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Tendency to Circular Economy: Reuse of Architectural Elements

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Abstract

Urbanization and building production that accelerate with globalization, cause excessive resource consumption and waste generation. The circular economy concept which is a contemporary economy approach, has been developed to solve this environmental and economic problem. The construction sector and architectural practice that provide building production need innovative solutions through the circular economy concept, as they consume different resources and produce waste crises. The circular economy concept is applied with the "adaptive reuse" approach in the field of architecture. One of the important applications of the concept of adaptive reuse is the reuse of architectural elements and materials. However, the relationship between the concept of circular economy and the reuse of architectural elements can be developed by examining several recent projects and its advantages. In this article, it is aimed to examine the relationship of this architectural reuse approach with the circular economy concept and to emphasize its importance. For this purpose, the theoretical perspectives and effects of circular economy were examined in the first part of the article, and the reflections of the circular economy concept on architecture were given in the second part. This section continues with description of the comparative analysis methodology that relates the building life cycle and circular economy principles to examine the architectural projects built as an example of circular economy paradigm. In the third chapter, two architectural sample projects built in China and France were selected and introduced. Being pioneers in their countries in circular economy approaches and the different environmental policies of countries have been effective in the selection of examples from different geographies. The fourth part consists of analyzing the projects according to circular economy parameters using comparative analysis method. In the last section, analysis results show that although China is one of the pioneers in adopting circular economy principles with architectural design and building life cycle, it has been found that France considers circular economy design from a broader perspective. Also, the design approach with circular economy criteria in different stage of building life cycle is gaining momentum over the years through national and local governments and collaborations. It is recommended that technological design systems such as BIM can be developed as integrated cloud systems that can share information from other sectors. Because the building life cycle is not only related to the architecture and construction sector. It is a cyclical system and economy that works with different sectors such as supply and waste management.

Keywords: circular economy, adaptive reuse, architectural elements.

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1. INTRODUCTION

Developing technology has created the basis of globalization by changing production and consumption patterns. Especially in the post-1980 period, it is seen that globalization and neo-liberal economic policies have marked the production-labor organizations and regulation mechanisms, cities have been shaped according to this geographical-spatial scales and hierarchies in the world (Brenner 2001). The change in the type of production, that is the economic element, has a special weight in the definition of urbanization (Keleş 1997). Urbanization has accelerated with the importance of the economic elements. Starting from these periods, the production of new buildings has caused large-scale demolition and waste generation. In this cycle of destruction and reproduction, the environmental effects of the buildings have increased negatively. Especially with the production of new buildings, energy consumption and CO₂ emission have increased. This emission is examined as carbon footprint defined as "the measure of the total amount of carbon dioxide emission that is directly or indirectly caused by an activity or accumulated over the life stages of a product" (Wiedmann and Minx 2008, 4). The increase in emissions or carbon footprint harms the environment.

Worldwide measures and regulations to minimize the environmental damage caused by urbanization made innovative solutions obligatory in the field of building materials and the entire construction sector (Candemir, Beyhan and Karaata 2012, 25). The limited resource of raw materials and materials used in the production of new building highlights material selection and secondary usage (Uzkut 1974). Secondary and tertiary usage affects the material life cycle. In order to solve the problem related to material, sustainable production and consumption models in different disciplines have been researched. Due to the fact that the problem has an economic aspect in addition to its environmental aspect, and sustainability cannot be applied efficiently in the current economic system that causes waste crises and consumes limited resources different approaches have been sought (Önder 2018). First of all, alternatives have been developed to existing production systems that cause the problem. One of these approaches is a production model based on "circular economy". The model has been legalized by the European Commission in published the Circular Economy action plan in 2015 in

many different sectors as circular economy packages in 2015 (Bruyninckx 2017).

However, there is not enough practice in architectural discipline, which has a large shareholder in production and consumption. The model has been developed in the field of architecture as "cradle to cradle design" that is "an ecologically intelligent approach to architecture and industry that involves materials, buildings and patterns of settlement which are wholly healthful and restorative" in 2003. (McDonough and Braungart 2003). New reflections of the circular economy in architecture have stood out with the approach to adaptive reuse of building and architectural elements. Adaptive reuse is the process of reusing an obsolete and derelict building by changing its function and maximizing the reuse and retention of existing materials and structures (Shahi, et al. 2020). In addition, adaptive reuse is also applied at different scales, with the reuse of building materials through repair and recycling. For the development of these applications, it is necessary to examine the concept of adaptive reuse in the circular economy model. In this article, it is aimed to investigate the adaptation of the model to architecture and architectural elements within the framework of the definition and stages in the literature. For this purpose, the research was organized in six parts.

The first part considers description and discussion of the methodology that analyses the building life cycle and circular economy applications to assess the selected architectural projects. The second part consists of the theoretical perspectives and effects of circular economy were examined in the literature. The reflections of the circular economy concept on architecture were presented in the third part. In the fourth section, two architectural projects built in China and France were selected and introduced to examine unique environmental and social contexts. The fifth part is evaluated the projects according to circular economy parameters using the comparative analysis method. In the sixth section, analysis results are evaluated, inferences and suggestions were discussed.

2. DATA AND METHODOLOGY

In this study, a comparative methodological analysis approach was developed to examine the design thinking process for circular economy paradigm. Prior to

the development of methodological analysis, an interdisciplinary and comprehensive literature review on the circular economy was conducted, starting from the meaning and scope of circular economy. Besides, the existing architectural projects that can be associated with circular economy criteria and their relations with the other sectors were examined. Therefore, the research was conducted in the field of circular economy and architecture not only from theoretical but also practical point of view. The research scope consists of examining the principle of "reuse", one of the circular economy criteria, on architectural elements. After determining the scope of the research, the analysis method improved to assess architectural reuse starting from the measurement of the life cycle of building phases (material-architectural design, construction, utilization, demolition-adaptive reuse) and circular economy criteria (3R-Recycle-Reuse-Reduce) in different aspects such as resource-based production, local delivery systems, material choices (Table 1). Hence, this approach can be assessed at the intersection of different disciplines as supply-chain management, waste management, construction management. Moreover, the comparative method provides synergies visible between industries and actors at the framework of the circular economy. This method can be evaluated design measurement tool to examine existing design approaches and early stages of feasibility analysis in the architectural field.

The measurement table is shown in Table 1, the analysis of the stages in which the architectural elements are reused according to the circular economy criteria in the building life cycle. However, since the circular economy is related to the macro-economic and social perspectives of the countries, the location of the selected project area should be analyzed comprehensively before evaluating the architectural approaches. Within the scope of this research, the concept of circular economy was first examined on a country basis, and then the comparative analysis in Table 1 was applied by going down to the case studies.

For this purpose, two architectural examples from different geographies have been chosen to analyze

detail of the reuse of building elements from the perspective of the circular economy, architecture, and the other sectors after the assessment of macroeconomic and social contexts of countries. Besides, in order to measure the development of the circular economy concept in designs, examples made in different years were selected and assessed in the developed measurement table (Table 1)

Criteria \ Process	Recycle	Reuse	Reduce
Development of architectural elements			
Architectural Design			
Construction			
Utilization			
Adaptive Reuse & Demolition			

Table 1. Measurement chart

3. CONCEPTUAL OVERVIEW OF CIRCULAR ECONOMY

The current economic system is based on the "buy-make-consume-throw" approach, which is a traditional model focusing on consumption (Sariatlı 2017). This approach has been called the "linear economy" model.

Linear economy principles start with the raw material design and end with the waste stage that is shown in Figure 1. Linear economy has two apparent problems: overuse of finite resources and excessive waste generation (Aldemir and Kaypak 2008). These main problems have affected the economy and environment since globalization and fast urbanization. In the



Figure 1. Basic steps of Linear Economy

linear economy approach, the first priority from the planning of the production process is the low-cost structure, high sales and excessive motive of profit. Also, in this process, the first priority is industry rather than environment. With the realization and proof of the environmental damage caused by this approach, the search has begun for a new sustainable development approach (Önder 2018). This problem is seen in many different sectors, especially construction sector. New economic models have been developed to solve this problem. One of them is 'Circular Economy'. The model was first used in 1976 by Stahel and Reday for industry-based economies. The circular strategy was developed primarily to solve the problem of waste prevention, regional employment creation, efficient resource usage, and material consumption in the industrial sector (Geissdoerfer, et al. 2017). The model differs from the linear economy in all sectors, in terms of increasing profitability by reducing costs, preventing and recycling waste with a protective approach.

Circular economy is defined by European Commission as “a strategy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized”. (Commission 2015). In addition to this, European Commission has specified circular economy as

an essential strategy for sustainable development, low carbon emissions and resource-efficient and competitive economy. With these definitions, it is seen that the model is an innovative design method for all sectors and is a strategy at the intersection of environmental and economic sustainability.

The basic principles of circular economy consist of "Recycle-Reuse-Reduction-3R" (Liu, et al. 2017). As seen in the Figure 2 and 3, outputs are continuously transformed into inputs. According to these basic steps, it differs from the system of linear economy where outputs are not used.

Recycle stage in the model is defined in the literature as "transforming waste into a new material and using it as a raw material" (Gürer, Akbulut and Kürklü 2004). While recycling ensures the conservation of resources, it also saves energy by shortening the processes used in raw material production. In this process, it also reduces the raw material and material requirement and reduces the overall costs.

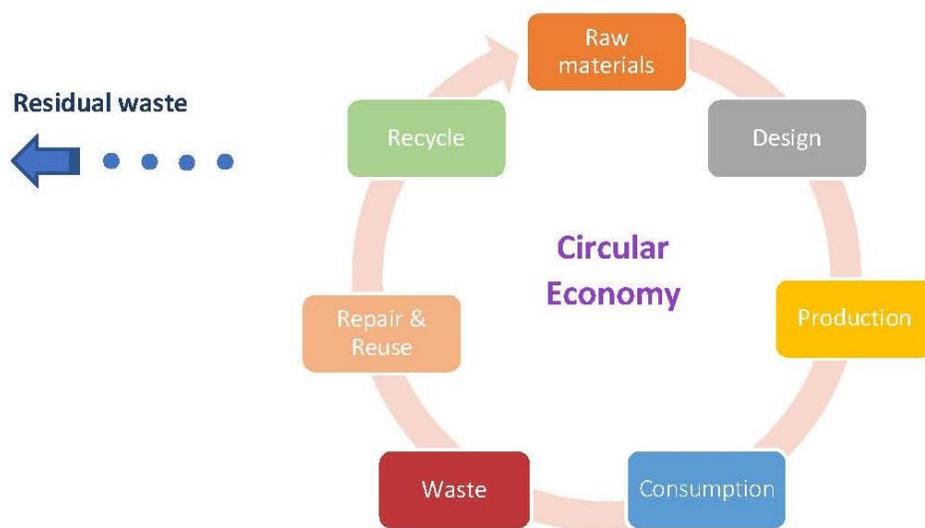


Figure 2. Steps of Circular Economy



Figure 3. Basic Principles of Circular Economy

According to literature re-use is defined as “the use of wastes either completely or partially in the production of other products through repair, renewal or reproduction” (Yang, Zhou and Xu 2014). Unlike recycling, no new product emerges at the end of this process. This stage has become prominent in today's circular economy approach, with less energy consumption than recycling and provides more cost reduction.

The reduction phase, on the other hand, refers to the reduction of wastes and pollutants generated in production and consumption processes (Yang, Zhou and Xu 2014). In other words, it is to minimize the carbon footprint of the product during the production and usage step. This process involves using non-polluting, durable and easily recyclable materials, using renewable energy; control systems consist of predicting waste management and using appropriate technologies.

3.1. The Benefits of Circular Economy

Circular economy uses principles based on durability, renewability, reuse, repair, replacement, upgrade, refurbishment, and less material use, which entails rethinking products and services (EU-LAC Foundation 2018). According to MacArthur Foundation (2015) works about circular economy, instead of linear consumption, which is reaching its limits, circular economy has both operational and strategic benefits at micro and macroeconomic levels. Besides, the World Sustainable Development Business Council (WBCSD) and The Consulting Group (BCG) have worked with companies on implementation of circular economy, and their research has shown that the implementation of circular economy boosts innovation for

efficiency and gains competitiveness by 97% (WBCSD 2018). More than half of the corporate interviewees have stated that their use of the principles of the circular economy contributed to increasing profits (EU-LAC Foundation 2018). Also, regarding to MacArthur Foundation report in 2014, the circular economy is a restorative and renewable business system, and this new business model has material savings estimated to be more than a trillion dollars (MacArthur Foundation 2014).

Moreover, the circular economy supports the environmental-friendly approach as opposed to the linear economy. Also, this approach supports inclusive cleaner production system with innovative clean technologies. Benefits will be obtained, not only by minimizing use of the environment as a sink for residuals but – perhaps more importantly – by minimizing the use of virgin materials for economic activity (Andersen 2006). Because of all of that, the circular economy is seen as the primary model for all sectors as it supports the continuous transformation of materials and cycle with technological innovations.

3.2. The Spread of Circular Economy

The concept of circular economy has been accepted as a strategy in many countries. The concept has also gained transaction with policymakers, influencing governments and intergovernmental agencies at the local, regional, national, and international level. Germany was a pioneer in integrating the Circular Economy into national laws, as early as 1996, with the enactment of the “Closed Substance Cycle and Waste Management Act” (Su, et al. 2013). After Germany, China adopted this strategy earlier than the other

Asian countries. Since the rapid urbanization, economic growth and environmental pollution, China needed a new development plan and strategy. Especially, after scholars' proposal of the concept of circular economy in China in 1998, central government formally accepted the circular economy as a new development strategy that aims to alleviate the contradiction between rapid economic growth and the shortage of raw materials and energy in 2002 (Su and Zhou 2005). This was followed by Japan's 2002 "Basic Law for Establishing a Recycling-Based Society" (METI 2004). After these regulations, China developed and expanded this strategy in 2009 with "Circular Economy Promotion Law of the People's Republic of China" (Lieder and Rashid 2016). In addition to this, supranational bodies have also incorporated circular economy concerns, most notably the EU's 2015 Circular Economy Strategy (Commission 2015). Especially, after the EU's regulations, the circular economy concept spread to European countries.

The widespread national and international regulations made governments to regularize production and waste system of all sectors. Moreover, many disciplines such as from the fields of economics, architecture, construction, management, law, and sociology started to contribute their different perspective on circular economy, and environmental and economic professionals also have gained a broader awareness. As a result, while concepts such as green supply chain management, green building, and adaptive reuse of the building and architectural elements

are prominent in the existing literature, they will attract more attention in the future.

4. CIRCULAR ECONOMY IN ARCHITECTURE

In order to understand the advantages of the circular economy in architecture, it is necessary to examine the results of the linear economy in architecture. The current linear economy system is the basis for the excessive use of resources and the emergence of waste crises in the architecture and construction sector. In addition, it decreases the utilization of existing structures and materials and increases urban sprawl, as it relies on continuous consumption and new production. This situation is completely against the principles of circular economy that is suggested the reuse, recycle and reduce of buildings and materials and also causes economic and environmental problems in congested cities where need new lands. Besides, the construction industry and architectural practice have produced many different buildings. However, as seen as in Figure 4, they rank the first in all sectors in terms of consuming raw materials and natural resources in this production and utilization process, therefore they have large environmental-economic effects. Considering that raw materials are among the main energy sources and consist of these, it is seen in Figure 4 that buildings consume more raw materials and energy than the other industries.

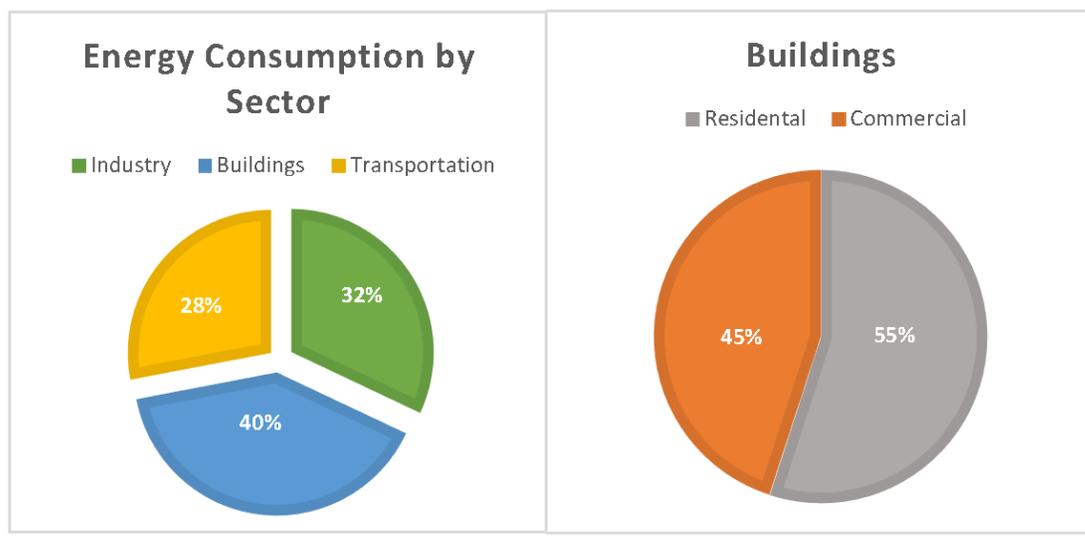


Figure 4. Energy consumption by sector (adapted from DeSimone and Fajilla 2019)

The amount of consumption varies in different continents. For instance, the built environment in Europe uses 1.8 billion tons of primary raw materials directly, which means 25% of the demand (Arcadis and WBCSD 2018). Besides, the built environment ranks first in environmental impact with its 34% waste share (Foundation 2018). Nowadays, as a result of the acceleration of urbanization and the increase in building production and utilization, gas emissions have increased by approximately 45% from the 1990s to

2019 (Agency 2019). As seen in Figure 5, the consumption of limited energy resources and the resulting carbon emissions tend to increase. In addition, it can be deduced that fossil fuels, which are the main resource of many architectural elements in the construction sector, are used more than other sectors and therefore gas emissions can be higher. In this case, it is seen that the selection and reuse of building materials have increasing importance in the field of construction and architecture.

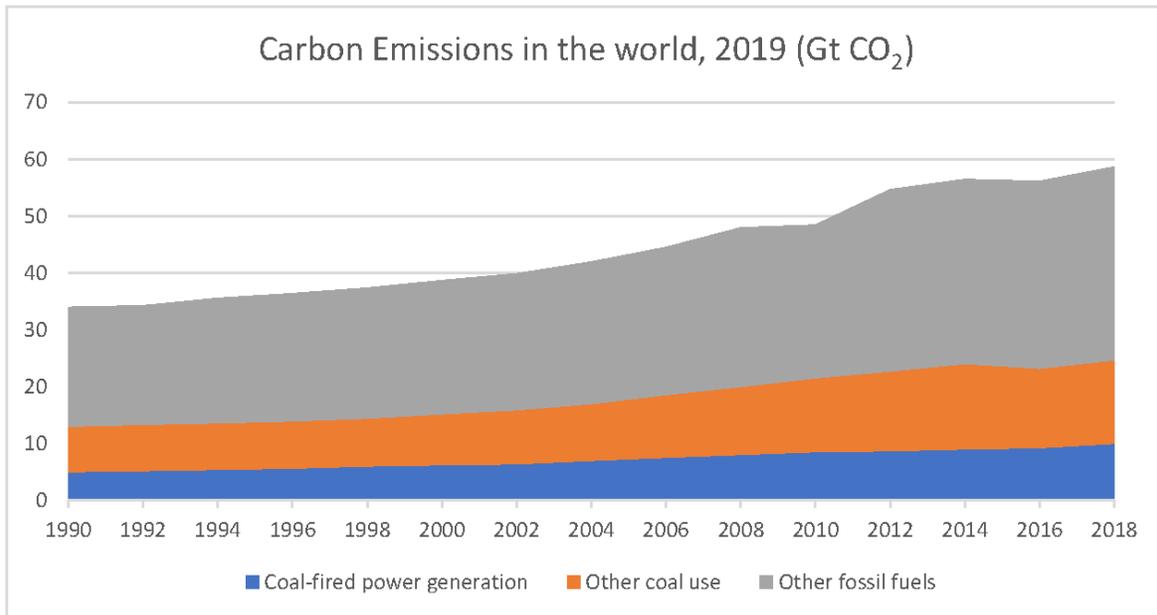


Figure 5. Adapted from International Energy Agency (IEA) CO₂ emissions in the world, 2019

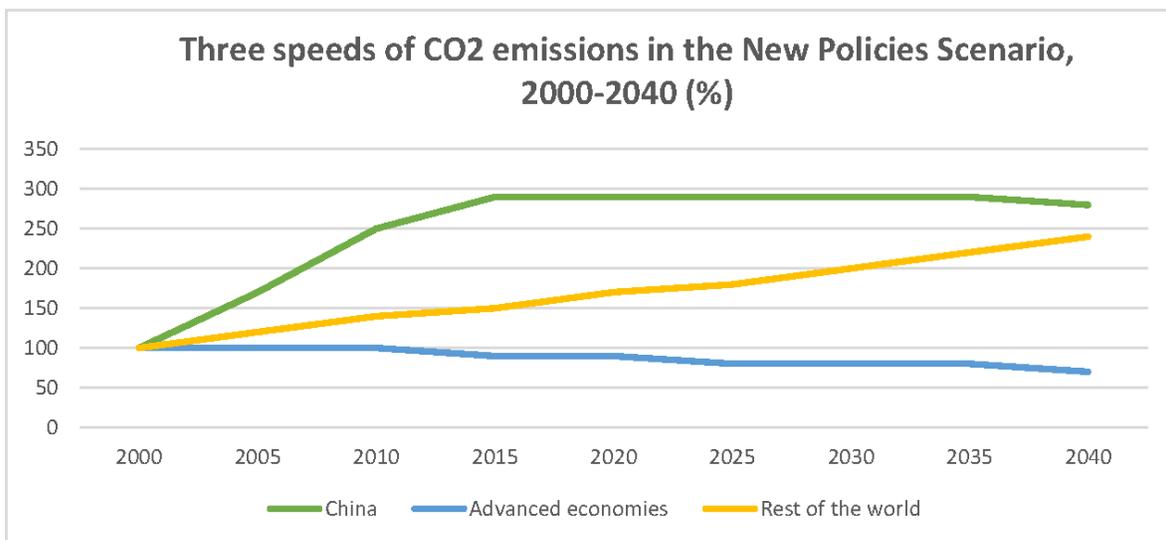


Figure 6. Expectation of CO₂ emissions until 2040, adapted from International Energy Agency (IEA) public data, 2019

In addition to this, according to IEA's studies, it is expected that CO₂ emissions will accelerate until 2040 in some countries except advanced economies and China. (Agency 2019). Figure 6 explains the prediction of future emissions that tends to decrease in advanced economies accepted the circular economy model as a policy instead of the linear economy. As indicated in Figure 6, countries in the rest of the world tend to increase their CO₂ emissions. In this case, the urgency of the adoption of the circular economy in these countries is seen. Besides, Figure 6 reports the success of China's circular economy policy adopted in the 2000s. According to the chart, this policy has helped the country to decrease its CO₂ emissions growth rate.

Moreover, CO₂ emission increases with the use of modern materials such as steel and concrete in the

production of new buildings. Figure 7 shows CO₂ emissions of building materials. Because of the lack of awareness of emissions in the design process, has increased its rates. This emission increase rate would be reduced with the awareness of the environmental effects of building materials, especially architectural design processes.

All environmental-economic factors have led investors, architects to explore the circular economy process and to design buildings within the concept of circularity. Circularity can be processed in architecture at various design scales:

1. Adaptive reuse / Refunctionalization of buildings in case the end of their existing functional usage.
2. Reuse of building / architectural elements and materials

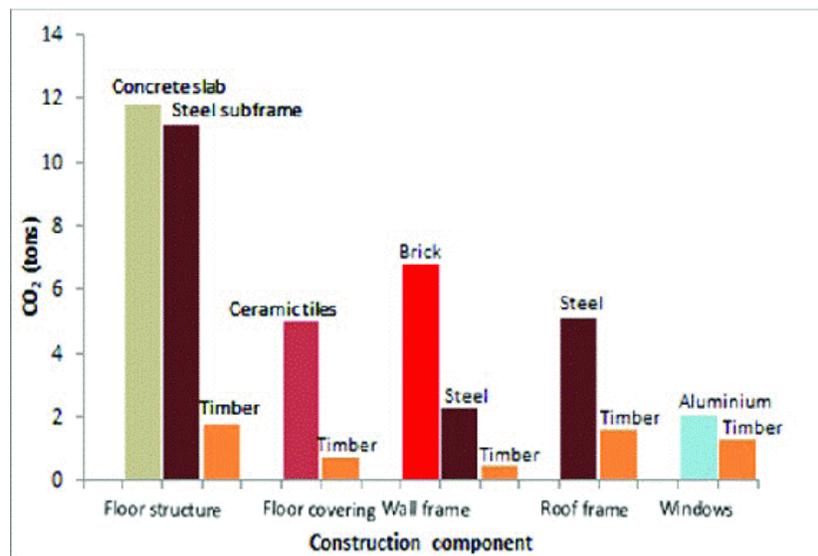


Figure 7. CO₂ emission of building materials (Meddah 2017)

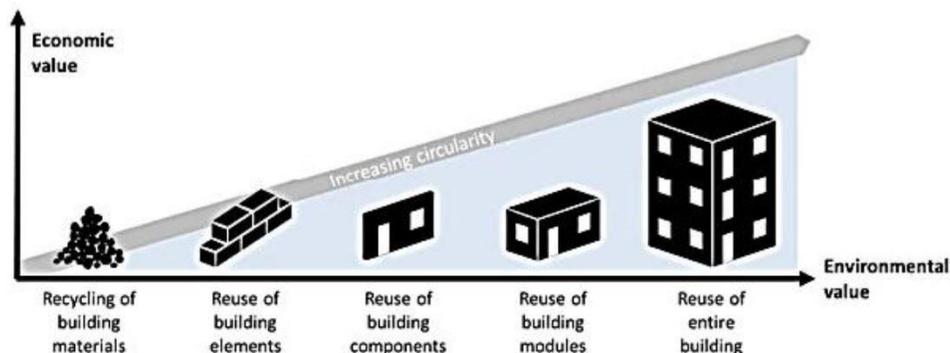


Figure 8. Increasing circularity (Eberhardt, Birgisdottir and Birkved 2019)

3. Recycling of building materials

As seen in Figure 8, as the scale of the building and material increases, circularity increases depending on environmental and economic protection / value.

All of these approaches can be evaluated as a design method to reduce the negative impacts of environmental and economic factors. One of these approaches is 'reuse of building / architectural elements and materials' used in production of new buildings. This design method gains importance due to its energy-saving efficiency and low-cost structure around the world.

Reuse of building elements and materials depends on the life cycle of the material. The linear structure of the process of material life shown in Figure 9, which is parallel with the current production model with the linear economy, causes waste, energy consumption, and costs by demolishing structures and materials. In order to solve this problem, it is necessary to make loop the life process of building and materials with this design concept.

The repair and development of the building elements that make up the building maintain the cycle through reuse without destruction, complying with the circular economy criteria. Since the materials used in building production depend on the global ecosystem, the lack of raw materials reduces their production. For this reason, it is important to extend the life of building elements and reduce material consumption. In this context, reusing materials by repairing and recycling supports profitability by reducing construction and waste costs. Repair and reuse of materials are more common as it costs less than recycling through technical processes. Materials such as solid wood, structural steel parts, coatings, glasses, partition walls, bricks can be cited as examples of these elements. Reusing the elements of the old building is an approach that needs to be considered before shredding tons of rubble and directing it to landfills and starting a design from scratch after the decision is

made to renovate the buildings. This approach gains importance during the renewal of built environments in city centers.

Moreover, the reuse of architectural elements reminds the identity of the old building and the region. Architectural contexts can be deepened in some geographies by establishing a relationship between reused materials and new functions. Besides, the reuse of region-specific materials in new productions requires local expertise, resulting in development based on local employment and local business models. Also, with the choice of local suppliers, energy consumption, emissions and costs can be reduced through logistics.

Another approach made in architecture within the framework of circular economy is seen in the recycling of used architectural elements that have completed their physical life, improving their strength and aesthetics by subjecting them to technical methods. Today, this method has become a new design tool in architectural community, and the used building materials collected under the name of 'urban mining' are divided into pieces and used for different purposes. In addition, recycle and urban-mining can be considered a term that symbolizes creative approaches with the support of technology without using natural resources. Moreover, this approach encompasses many business sectors such as the quantification of secondary raw materials, recovery and recycling techniques, transformation of recycling models into structural information, profitability analyzes, and industries that process and recycle valuable materials. These sectors that need to be adapted are the construction sector and architectural practice. In addition to these sectors, new delivery management, advanced supply-chain system and construction management must support and work these sectors. The form and content of the linear process from the design stage to the demolition stage in this field requires innovative perspectives. In this context, in the process of increasing urbanization and new building production, it has been observed that the adaptive reuse of existing building



Figure 9. The linear life cycle of building & materials

materials and elements and their inclusion in the design has been found to be environmentally and economically beneficial.

The approach of developing different materials by recycling building materials with various technical methods also has environmental and economic benefits, but it is understood that it is not as efficient as other approaches because it requires many industrial processes. Also, the combined use of these approaches can significantly eliminate the negative effects. The aim of the circular economy is to reduce waste production and material consumption, and the applications of architecture at the scale of building materials have been examined within the framework of the "reuse" and "recycling" approach (Figure 10). However, in order to develop a more efficient "reuse" approach, it is necessary to examine the details of its implementations from different perspectives.

5. REUSE OF ARCHITECTURAL ELEMENTS: CASE STUDIES

In this article, two architectural projects that located in different geographies were selected and analyzed with a comparative method. In the selection process, pioneers countries in circular economy approach,

their different social and environmental policies and their different reflections to design have been effective. For this purpose, unique and distant geographies China and France were chosen to compare their social-economic-environmental policies, design approaches and its relationship. Besides, these examples were built from the perspective of the circular economy concept according to their architects. These approaches were examined starting from the design thinking to demolition processes according to the literature and practice of the circular economy criteria. For this analysis, Ningbo History Museum from China and Circular Pavilion from France were selected as case studies.

5.1. Ningbo History Museum

Globalization has caused rapid development and urbanization in China as well as in the whole world. Cities in China also have reacted to this speed by showing a growth and expansion tendency. During this growth, the destructions and wastes in the city centers increased and the urban fabric has been damaged. Besides, China's economy needed some legal regulations the result of rapid globalization.

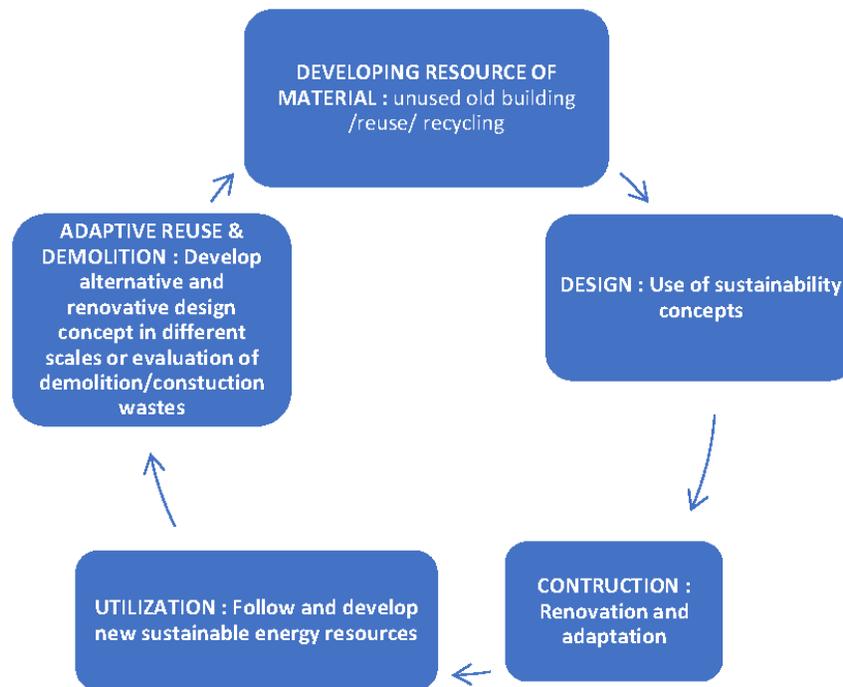


Figure 10. The circular life cycle of building & materials

All of the different results of rapid globalization make special research obligatory. This research ended up with the concept of circular economy. After that, China has transformed the concept of the circular economy into national law. In the following years, different regulation and approaches have been spread to many sectors such as architecture and urban planning. In the light of these different developments, it has been planned to revitalize the urban texture and economy by preservation and rehabilitation. (Chau 2015)

As a result of the re-planning approach of the city of Ningbo, a reconstruction project was initiated to revitalize the urban texture. However, according to Wang Shu (Chau 2012), the revitalization project demolished the city and standardized all the buildings, ignoring the historical context of the city and the reality of the large population in China. According to the new master plan, the buildings must be 100 meters apart and the maximum height must be limited to 24 meters.

In 2008 is the year when regulations on the circular economy came to the fore, a monumental project has planned to introduce the history of Ningbo within the scope of the reconstruction project. Moreover, before the project, traditional houses in 30 villages around the project area were demolished within the scope of reconstruction. As a result, wrecks were formed in a large part of the city. Architect Wang Shu, who designed the project in 2003-2008, used old

materials in the debris to challenge the "professional and soulless architecture" widely practiced in China. In addition, after the demolition, most of the 1000-year-old bricks and tiles were improved and included to the design thinking process. With this approach, it is aimed to prevent damage to the collective memory of the residents, tradition and culture passed down from generation to generation. Besides, the reuse of materials attached the added value to the waste.

Ningbo Historic Museum can be evaluated as a monumental, built on an area of 30,000 square meters in the area where the rubbles are located. Also, it is an asymmetrical construction, measured 144 m long, 65 m wide and 24 m high as seen in Figure 12. In this context, the addition of the history museum function as a reminder to the place of the demolished traditional houses and the use of old and recycled bricks in the building strengthen the relationship of material-function-location.

In addition to the reuse of the bricks of traditional houses that were destroyed on the facades of the building, exposed concrete was used as seen in Figure 13. A unique texture is given to the exposed concrete



Figure 11. Location of Ningbo, Google Maps



Figure 12. Ningbo History Museum. Source: Wikipedia Commons, "File: South Gate of Ningbo Museum.jpg" by Siyuwj is licensed under CC-BY-SA-3.0



Figure 13. Ningbo History Museum. Source: Wikipedia Commons, "Ningbo History Museum" by Santo Chino is licensed under

with the molds made of bamboo that is the vegetation cover of the region. In this way, a common language was created between traditional and modern materials, and modern materials were interpreted with local elements. The harmony of different materials is considered by its surroundings as "a massive concrete fortress, a cultural foundation that stands against the largely scattered irregular texture of the new city". Wang Shu, referring to the traditional interest in natural forms and materials, as clearly exemplified in Chinese landscape paintings, he designed

the building as a mountain as a representative natural form, supporting the Chinese people to find their lost and hidden culture, especially for city dwellers alienated from nature (Chau 2012).

The process of improving traditional bricks on the facade of the building and adapting to the new building requires special knowledge. These bricks can be used with Wa pan technique in the region. Wa pan technique was frequently used in traditional Chinese architecture by local artisans as shown in Figure 14. This



Figure 14. Ningbo History Museum-Wa Pan wall. Source: Wikipedia Commons, "Wa Pian Wall" by Santo Chino is licensed under CC BY-NC 2.0.

technique is the first used in the region to quickly rebuild the villages after the natural disasters that frequent the area. With this technique, ceramic bricks and tiles were diversified with different variations and applied to the facades as seen in Figure 14. The technique is important to provide less costly than modern materials and can be applied quickly. The Wa pan technique has been applied to building in collaboration with local artisans. With the help of this cooperation, employment was provided through traditional productions, craftsmen and local delivery system in the region. Therefore, Wa pan technique and Wa pan walls still maintain their sustainability feature in China (Pheng, et al. 2016).

The building can be considered as a reflection of the designer's expressions *the opposite of spectacular skyscrapers made of reflective glass and pale steel and concrete, the use of natural materials, and the need to integrate with its surroundings.*

Wang Shu focuses on the use of traditional building techniques in new building designs and engagement of traditional craftsmen, with reference to circular economy principles. In this way, Wang has attained local craftsmanship and revives traditional materials by combining them with modern. During the construction process, traditional materials were sent to the original creators for renewal. With this project Wang Shu became the first Chinese architect to receive the Pritzker award in 2012.

5.2. The Circular Pavilion

Circular Pavilion was built in Paris, France in 2015, with the circular economy concept in design process. As the name suggests, Circular Pavilion contains 'cyclicality'. However, this circularity was reflected not by its form or function, but by the fact that the design process includes and conforms to circular economy criteria. This pavilion is a structure that emphasizes the depletion of natural resources and the goal of "Zero Metropolis Waste" and demonstrates the potential for reuse in architecture by conforming to the context of COP 21 (2015 United Nations Conference on Climate Change) in Paris.

The facade of the building consists of 180 wooden doors abandoned during a residential rehabilitation operation in the 19th district of Paris. In the interior, mineral wools that were collected from the unused part of roof insulation of a supermarket. In addition, the furniture in the interior was generated by collecting and painting 50 wooden chairs that were not used

in Paris. Hanging lights were brought from the area's public lighting warehouse. Except for the frames and insulation, all the work was done by the technical services of the Paris City Municipality.

While the wooden framework, which is the structure of the building, is made of unused and leftover material on the construction site of a nursing home, the floor and partition walls consist of the walls taken from the old exhibition spaces. The outdoor terrace is built with wood that is used in events held in Paris at different times. With these features, approximately 60% of the materials have found a second life.

A better focus on existing resources and materials in building design not only reduces primary resource consumption, but also prevents the generation and build-up of waste that needs to be dealt with later. While the building was designed to be detachable and placed in the Parvis de l'Hôtel de Ville square in Paris, it hosted exhibitions, workshops, conferences and discussions. With the establishment of the building in the square, it is aimed to make the circular economy-design relationship visible. The pavilion was dismantled at the beginning of 2016 and permanently rebuilt as the clubhouse of a sports association in the 14th district of Paris.

The structure reduces its negative impact on the environment with its detachable construction. It was developed with support from local governments during the design process. In addition, it is an important example in the intersection of the circular economy-design in terms of improving the reuse of secondary materials by establishing relationships with contemporary forms and functions.

6. ANALYSIS

Within the scope of the study, a methodological method was developed to examine design thinking process for a circular economy paradigm. For this purpose, Ningbo History Museum and Circular Pavilion were examined in detail using the comparative analysis method in terms of the compliance of building life cycle practices with circular economy criteria. The building life cycle in architecture that is material-architectural design, construction, utilization, and demolition was compared with the circular economy criteria (Recycle, Reuse, Reduce).

The selection of buildings in different geographies and years provides the opportunity to question the circular economy policies and cooperation of various regions and administrations. Moreover, this method has redefined different architectural design thinking framework and relationships between the construction management, supply-chain management, waste management. In addition to this, the method can be used to analyze various architectural projects or elements in terms of the circular economy.

6.1. Analysis: Ningbo History Museum

With the negative effects of rapid urbanization beginning to be seen in China, the concept of circular economy policies and laws has gained importance in all sectors especially in new building production. From the perspective of architect Wang Shu, the adaptation of the circular concept to the architectural design stages can be effective with the creation of a common language with local and modern. In the Ningbo History Museum, which is a project where this perspective is applied, local and original architectural materials have been used by recycling and reusing as seen in Table 2. At this stage, it can be referred energy consumption, CO₂ emissions and costs have been significantly reduced because of the secondary usage.

In the architectural design phase, modern materials such as exposed concrete have been adapted with re-used materials, shaped with molds in original form and material (bamboo). In addition, the reuse of old materials references the function of the history museum. However, considering that the architectural design phase also includes interior design, the original old elements used in the facade of the building were not reflected in the interior, and reused or recycled materials were not used in the interiors. With this feature, the building shows that the design approach is open to improvement. For interior improvement, an integrated delivery-supply system can be developed and used by advanced cloud technologies to adapt to the overall architectural design concept. The engagement and cluster of knowledge can strengthen the relationship and approaches in the early design process.

Collaborating with local craftsmen and producers during the construction process, it contributed to employment, the traditional production process was also kept alive, and the cost was greatly reduced. At this stage, as Wang Shu stated, the support of local governments has the potential to spread their positive effects to a large scale such as the development of the country (Miao 2021) In this respect, the project made

Ningbo History Museum-2008-CHINA			
Criteria	Recycle	Reuse	Reduce
Process			
Development of architectural elements	X (Recycling ceramic tiles, production of clay brick from rubbles)	X (Reuse of ceramic tiles, brick directly)	X (Reduce of emissions and wastes with secondary material usage)
Architectural Design		X (Incorporating material design/repair into architectural design)	X (Reduce of energy of transport by production with local artisans)
Construction			X (Reduce of energy, cost and time by using local labour)
Utilization		X (Revitalizing memory and identity by material reuse)	
Adaptive Reuse & Demolition			

Table 2. Analysis of Ningbo History Museum

a great contribution to the design with circular economy concept

In the usage phase of the building, the original materials reused on the facade are a memory element that reflects the past to the locals and tourists and added the social dimension to the circular economy criterion.

The reuse of architectural elements concept realized in all life cycle stages of the Ningbo History Museum project is shown in Table 2.

As a result of this subsection, the History Museum is a pioneer in the relationship between the circular economy and design in China, and examples including

this relationship have increased since 2008, the year of construction.

6.2. Analysis: The Circular Pavilion

The Pavilion was built with circular economy criteria to draw attention to the issues of zero waste and climate change in line with the 2015 European Commission report and is located in an important square in Paris.

In the material choice phase of the Pavilion, old and unused architectural elements were repaired and reused, and recycling method was not used because it was more costly. A relationship has been established with the reused materials and the scale, form and

Circular Pavilion-2015-FRANCE			
Criteria	Recycle	Reuse	Reduce
Process			
Development of architectural elements		X (Reuse of wooden doors and framework, woods, floor covering and partition wall)	X (Reduce of emissions and wastes with secondary material usage)
Architectural Design		X (Incorporating material design/repair into architectural design)	
Construction		X (Reuse of materials that is detachable and movable)	X (Reduce of emissions and wastes with detachable material usage; collaboration with local organizations)
Utilization		X (Revitalizing memory and identity by material reuse)	
Adaptive Reuse & Demolition		X (Reinstallation in another location)	X (Waste reduction with the detachable structure)

Table 3. Analysis of Circular Pavilion

functions in the architectural design process. This relationship has increased the emphasis of the concept of circularity.

The fact that the materials reused during the construction phase are removable and easy to carry, significantly reduced energy consumption and costs. In addition, as the support of local governments increased within the scope of circular economy reports, procurement and reuse of different materials increased in this process. However, the project is open to development in terms of cooperation with local artisans and producers.

The doors that are reused in the usage phase, especially on the exterior, refer to the memory and sense of identity of the users. In the interior, the reuse of materials is also reflected in items such as furniture and lighting. However, the emphasis of these elements should be increased by establishing a relation-

The building is detachable and portable, significantly reducing waste generation, energy consumption and cost. It also strongly reflects the circular economy-design relationship with its re-functioning in another location for another purpose (Encore Heureux Architects 2015)

All the reuse of architectural elements approaches in the life cycle of Circular Pavilion are examined and shown in Table 3. According to Table 3, the reuse approach was applied in different stage and various way.

For the comparative analysis, Table 2 and Table 3 are merged to examine the differences as seen in Table 4. According to Table 4, Circular Pavilion project was found to be more successful than the other project, as the reuse of materials was adapted to the entire building life cycle. However, both projects were found valuable as they are pioneers in design approaches

Ningbo History Museum-2008-CHINA			
Criteria	Recycle	Reuse	Reduce
Process			
Development of architectural elements	X	X	X
Architectural Design		X	X
Construction			X
Utilization		X	
Adaptive Reuse & Demolition			
Circular Pavilion-2015-FRANCE			
Criteria	Recycle	Reuse	Reduce
Process			
Development of architectural elements		X	X
Architectural Design		X	
Construction		X	X
Utilization		X	
Adaptive Reuse & Demolition		X	X

Table 4. Comparative Analysis of Circular Pavilion

ship with the outdoor space.

according to the circular economy.

7. CONCLUSION

In this study, the definition of the linear economy system that causes the emergence of the circular economy and its effects on architecture are discussed. After that, the circular economy approach in architecture is classified and presented. Lastly, the relationship of the circular economy with architecture is examined through two architectural examples in terms of the reuse of architectural elements in new buildings. Ningbo History Museum and Circular Pavilion have been selected in this review as it is aimed to see the development and parameters of the circular economy applications. Evaluations were made through literature review, architectural discourse, and approaches.

As a result of the analysis and evaluations made, it has been observed that the circular economy criteria and the design idea, especially the reuse of architectural elements, have gained importance over the years. According to analyses, it is seen that the regulation and sanctions of the European Union Commission in the First Circular Economy Action Plan 2015 and recommendations of international auxiliary organizations such as titled *Towards a Circular Economy: Accelerating the Scale-Up across Global Supply Chains in 2014* have increased the practices. This development has been extended by national and local governments and collaborations, as seen in the examples of China and France. However, there is a requirement to the development of the circular economy concept to gain momentum, the support and engagement of regional organizations and country administrations must be increased by integrated communication system. It has been observed that the approach considered as a pioneer in China has been processed in a distant geography such as France with the conferences and sanctions. Considering the design practices in France, it is understood that compliance with the circular economy criteria has developed by various perspectives at the life cycle of building. However, the emphasis of these approaches can be spread to the whole of the building with recycle approach. In addition, it is important to articulate the detachability, mobility or flexibility dimension, which is another important parameter in terms of the circular economy, to the reuse approach in future building production.

As a general result, it is seen that the circular economy needs the engagement of different disciplines. Especially, the interactive supply-chain management system for the requirement of reused and recycling materials, elements; waste management system to decide which materials and elements can be saved

and repairable. Also, it is important that the calculation of material efficiency and its visualization must be connected to other disciplines such as the supply-chain system and architectural design stage. For this communication, an integrated information system and existing BIM (Building Information System) can be developed as a cloud system must be supported at the whole of interdisciplinary works and sectors for the circular economy concept. Also, this data analysis must check with empirical methods such as decision trees or machine learning for maximum efficiency of the project. In addition to this, the architecture and construction stage must be included this process. Before the architectural design, the feasibility analysis that also supports circularity and sustainability must examine with the other interdisciplinary partners through integrated cloud systems. Also, different administration stages should be incorporated into an integrated cloud system. It is seen that as a result of the review of projects and approaches, the circular economy is a circular and inclusive process not only for the life circle of a building or its element but also for different sectors and partners. The architecture and construction sectors have played an important and consolidative role in the circular economy. As a consequence, the architecture and construction sectors can be adapted to the integrated and developed cloud BIM system. Also, this system should be taught to young architects in different design studios.

In conclusion, there is a need for innovative solutions in the field of the construction and architecture in geographies other than China and France which have been analyzed in detail. Besides, the circular economy-design relationship and productivity perspectives in these countries are a matter of curiosity. With this study, it is seen that before the design process of the architectural projects, the world-scale studies and approaches should be examined and integrated design should be developed with the other disciplines. Also, it is seen that the communication and engagement of the other partners are the key element of the circular economy concept. In order to develop this approach, firstly, legal sanctions should be imposed on countries that have high energy consumption, and then countries should support projects through local governments. Furthermore, this collaboration should be merged the architectural design and construction phase of the projects by different approaches, such as the reuse and recycling practices in architecture should be spread by the circular economy concept. Also, the support and assessment of these projects

that are designed with the circular economy concept provide generating public awareness to the whole of the people.

References

Agency, International Energy. "International Energy Agency CO2 Emissions." *Expection of CO2 emissions until 2040, International Energy Agency (IEA) 2019*, <https://www.iea.org/data-and-statistics/charts/three-speeds-of-co2-emissions-in-the-new-policies-scenario-2000-2040>. 2019. Expection of CO2 emissions until 2040, International Energy Agency (IEA) 2019, <https://www.iea.org/data-and-statistics/charts/three-speeds-of-co2-emissions-in-the-new-policies-scenario-2000-2040> (accessed February 28, 2021).

Aldemir, Şenkan, and Şafak Kaypak. "“Eko-Ekonomi” Kavramı Ve Türkiye İçin Bölgesel Ölçekli Bir Değerlendirme." 2. *Ulusal İktisat Kongresi*. İzmir, 2008.

Andersen, Mikael Skou. "An introductory note on the environmental economics." *Sustain Sci*, 2006: 133-140. <https://doi.org/10.1007/s11625-006-0013-6>

Arcadis, and WBCSD. "Scaling the Circular Built Environment. Netherlands and Switzerland." *wbcds/Home/ Circular Economy/ Factor10/Resources*. December 4, 2018. <https://www.wbcds.org/Programs/Circular-Economy/Factor-10/Resources/pathways-for-business-and-government> (accessed February 28, 2021).

Brenner, Neil. «The Urban Question as a Scale Question:Reflections on Henri Lefebvre, Urban Theory and the Politics of Scale.» *International Journal of Urban and Regional Research*, 2001: 363-365.

Bruyninckx, Hans. " World Circular Economy Forum 2017, Helsinki, Finland. The European context, Source: European Commission, 2017; 2." Helsinki, 2017.

Candemir, Başak, Berna Beyhan, and Selçuk Karaata. "İnşaat Sektöründe Sürdürülebilirlik: Yeşil Binalar ve Nanoteknoloji Stratejileri." *İMSAD & TUSİAD Dergisi*, 2012: 25.

Chau, Hing-wah. "City, Tradition and Contemporary China from Wang Shu's Works to Review his Critical Practise with the City" *APCBEE Procedia 1 (2012) 40-45*. doi: 10.1016/j.apcbee.2012.03.008Chau, Hing-wah. "The Aesthetics of Reuse: The Materiality and

Vernacular Traditions of Wang Shu’s Architecture." *Unmaking Waste 2015 Conference Proceedings*. 2015.

Commission, European. "Closing the loop - An EU action plan for the Circular Economy." Brussels, 2015.

DeSimone Marilena, Fajilla Gianmarco. "Occupant Behavior: A "New" Factor in Energy Performance of Buildings -Methods for Its Detection in Houses and in Offices". *Journal of World Architecture*. Volume 2; Issue 2.2019

Eberhardt, L. C. M., H Birgisdottir, and M. Birkved. "Potential of Circular Economy in Sustainable Buildings." *IOP Conference Series: Materials Science and Engineering*. IOP Publishing, 2019. Vol. 471, No. 9, p. 092051. <https://doi.org/10.1088/1757-899X/471/9/092051>

The Circular Pavilion / Encore Heureux Architects" 21 Dec 2015. ArchDaily. Accessed 13 Sep 2021. <<https://www.archdaily.com/778972/the-circular-pavilion-encore-heureux-architects>> ISSN 0719-8884

EU. "First circular economy action plan." 2015 https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_en

EU-LAC Foundation. "Case Studies on Circular Economy Models and Integration of Sustainable Development Goals in Business Strategies." Hamburg, Germany, 2018.

Foundation, EU-LAC. "Case Studies on Circular Economy Models and Integration of Sustainable Development Goals in Business Strategies. Hamburg, Germany." *EU-LAC Foundation*. 2018. https://eulacfoundation.org/en/system/files/case_studies_circular_economy_eu_lac.pdf (accessed February 28, 2021).

Geissdoerfer, Martin, Paulo Savaget, Nancy Bocken, and Erik Jan Hultink. "The Circular Economy – A New Sustainability Paradigm?" *Journal of Cleaner Production 143: doi:10.1016/j.jclepro.2016.12.048.*, 2017: 757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>

Gürer, Cahit, Hüseyin Akbulut, and Gökhan Kürklü. "İnşaat Endüstrisinde Geri Dönüşüm ve Bir Hammadde Kaynağı Olarak Farklı Yapı Malzemelerinin Yeniden Değerlendirilmesi." *5.Endüstriyel Hammaddeler Sempozyumu*. İzmir, 2004. 28-36.

- Keleş, Ruşen. *Kentleşme*, 22. İmge Kitabevi, 1997.
- Lieder, Michael, and Amir Rashid. "Towards circular economy implementation: a comprehensive review in context of manufacturing industry." *Journal of Cleaner Production* 115, 2016: 36-51. <https://doi.org/10.1016/j.jclepro.2015.12.042>
- Liu, Lili, Yangyang Liang, Qingbin Song, and Jinhui Li. "A review of waste prevention through 3R under the." *Journal of Material Cycles and Waste Management volume 19*, 2017: 1314–1323. <https://doi.org/10.1007/s10163-017-0606-4>
- MacArthur Foundation. "Ellen MacArthur Foundation. Towards the Circular Economy: Accelerating the Scale-up Across Global Supply Chains." England, 2014.
- MacArthur Foundation. "Towards a Circular Economy Business Rationale for an Accelerated Transition." England, 2015.
- McDonough, William and Braungart Michael "Towards a sustaining architecture for the 21st century: the promise of cradle-to-cradle design". Sustainable building and construction, UNEP Industry and Environment April – September 2003 : 13-16
- Meddah, Mohammed Seddik. "Recycled aggregates in concrete production: engineering properties and environmental impact." *MATEC Web of Conferences*. EDP Sciences, 2017. Vol. 101. <https://doi.org/10.1051/mateconf/201710105021>
- METI. "Handbook on Resource Recycling Legislation and 3R Trends in 2003 ." *Ministry of Economy, Trade and Industry* . 2004. <http://www.gdrc.org/uem/waste/japan-3r/5-handbook-meti.pdf> (accessed February 27, 2021).
- Miao, Scarlett. "Amateur Architecture Studio's Works on Contemporary Chinese Architecture with Recycled Materials" 06 Jul 2020. ArchDaily. Accessed 12 Sep 2021. <<https://www.archdaily.com/942622/wang-shus-works-on-contemporary-chinese-architecture-with-recycled-materials>> ISSN 0719-8884
- Önder, Hüseyin. "Sürdürülebilir Kalkınma Anlayışında Yeni Bir Kavram: Döngüsel Ekonomi." *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, (57) , 2018: 196-204.
- Pheng, Canisius, Joyce Qin, Kan San, Ong Xuan, Ricco Wei, and Tan Hoe. "Wapan Technique used in Ningbo Historic Museum to Revive Traditional Chinese Construction Techniques." *Taylor's University, Asian Architecture Case Study Paper*, 2016.
- Sariatli, Furkan. "Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability." *Visegrad Journal on Bioeconomy and Sustainable Development*, 2017: 32. <https://doi.org/10.1515/vjbsd-2017-0005>
- Shahi, Sheida, Mansour Esnaashary Esfahani, Chris Bachmann, and Carl Haas. "A definition framework for building adaptation projects ." *Sustainable Cities and Society* 63 (2020)102345, 2020: 4. <https://doi.org/10.1016/j.scs.2020.102345>
- Su, B, A Heshmati, Y Geng, and Yu, X. "A review of the circular economy in China: moving from rhetoric to implementation." *Journal of Cleaner Production* 42, 2013: 215-227. <https://doi.org/10.1016/j.jclepro.2012.11.020>
- Su, Yang, and Hongchun Zhou. "Promoting Circular Economy Development a Basic National Policy." *Northern Economy*, , 2005: 8-10 .
- Uzkut, İsmet. «Dünya Hammadde Sorunu.» *Madencilik Dergisi*, 1974: Cilt : XIII Sayı : 4.
- WBCSD. *The World Sustainable Development Business Council (WBCSD)*. January 24, 2018. <https://www.wbcd.org/Programs/Circular-Economy/Factor-10/News/Implementation-Guide-to-the-Circular-Economy> (accessed January 26, 2021).
- Wiedmann, Thomas, and Jan Christoph Minx. "A Definition of Carbon Footprint." *CC Pertsova, Ecological Economics Research Trends*. 2., 2008: 55-65.
- Yang, Q. Z., Jifeng Zhou, and Kaihua Xu. "A 3R Implementation Framework to Enable Circular Consumption in Community." *International Journal of Environmental Science and Development*, 5(2);, 2014: 217-222. <https://doi.org/10.7763/IJESD.2014.V5.481>
- Yuan, Zengwei, Jun Bi, and Yuichi Moriguchi. "The circular economy: a new development strategy in China." *Journal of Industrial Ecology* 10(1-2), 2006: 4-8. <https://doi.org/10.1162/108819806775545321>

