Considerations in Design of Environmentally Sustainable Residential Kitchens

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ABSTRACT

Kitchen is one of the most functional parts of a house and therefore plays a crucial role in the sustainability of houses. The complexity of contemporary kitchens' multifunctionality along with considerable expenses of kitchens' components create additional importance for kitchens in architectural projects. On the other hand, Environmental degradation has become one of the main concerns of present era which threatens the lives of all species on earth including humans. As a result, environmental consciousness has grown drastically among humanity leading to an increase in demand for green and sustainable kitchens, which also adds to complexity of contemporary kitchen design. As sustainability is a multi-layered concept, while designing a residential kitchen, designers should consider various factors related to sustainability in all stages of design and construction. Despite the significance of the subject there is a lack of practical guidelines to help designers, particularly interior designers, in dealing with this very important duty. The aforementioned issues have driven this study to attempt for devising a practical guideline regarding the design of sustainable residential kitchens. First, a comprehensive literature review is carried on about sustainability, sustainable interior design and sustainable kitchen. Then, based on this inclusive study a practical guideline has been prepared to perform as a tool to help designers in design of sustainable residential kitchens. This guideline has been prepared with a focus on environmental issues and can also be used for educational purposes in schools of interior architecture. Further studies on the subject can be done which include all dimensions of sustainability (social and economic dimensions).

Keywords: sustainability, interior architecture, sustainable residential space design, kitchen design, sustainable kitchen

ÖZ

Mutfak, bir evin en işlevsel mekanlarından biridir ve bu nedenle evlerin sürdürülebilirliğinde önemli bir rol oynar. Çağdaş mutfakların çok işlevliliğinin karmaşıklığı ve mutfak donanımların yüksek maliyeti, mutfakların mimari projelerde ayrı bir öneme sahip olmasını sağlar. Öte yandan, çevresel bozulma, insanlar da dahil olmak üzere dünyadaki tüm türlerin yaşamlarını tehdit eden günümüzün ana kaygılarından biri haline gelmiştir. Sonuç olarak, çevre bilinci insanlar arasında önemli ölçüde artmış ve yeşil ve sürdürülebilir mutfaklara olan talebin artmasına yol açmış, bu da çağdaş mutfak tasarımının karmaşıklığına katkıda bulunmuştur. Sürdürülebilirlik çok katmanlı bir kavram olduğundan, konut mutfağı tasarlarken tasarımcılar, tasarım ve inşaatın tüm aşamalarında sürdürülebilirlikle ilgili çeşitli faktörleri göz önünde bulundurmalıdırlar. Konunun önemine rağmen, tasarımcıların, özellikle iç mimarların bu çok önemli görevle başa çıkmalarına yardımcı olacak pratik yönergelerin eksikliği vardır. Yukarıda belirtilen sorunlar, bu çalışmayı sürdürülebilir konut mutfaklarının tasarımıyla ilgili pratik bir kılavuz oluşturma girişimine yöneltmiştir. İlk olarak, sürdürülebilirlik, sürdürülebilir iç mekan tasarım ve sürdürülebilir mutfak hakkında kapsamlı bir literatür taraması yapılmıştır. Daha sonra, bu kapsayıcı çalışmaya dayanarak, tasarımcılara sürdürülebilir konut mutfaklarının tasarımında yardımcı olacak bir araç olarak kullanılacak pratik bir kılavuz hazırlanmıştır. Bu kılavuz, çevresel sorunlara odaklanarak hazırlanmıştır ve iç mimarlık okullarında eğitim amaçlı da kullanılabilir. Sürdürülebilirliğin tüm boyutlarını (sosyal ve ekonomik boyutlar) içeren konu hakkında daha fazla çalışma yapılabilir.

Anahtar Kelimeler: sürdürülebilirlik, iç mimarlık, sürdürülebilir konut tasarımı, mutfak tasarımı, sürdürülebilir mutfak

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BIM	Building Information Modeling
BREEAM	Building Research Establishment Environmental Assessment Method
C2C	The Cradle to Cradle
CFLs	Compact Fluorescent Lamps (Federal Minimum Standard, And Qualified Light Bulbs)
CO	Carbon Monoxide
EPA	Environmental Protection Agency
EPS	Expanded Polystyrene Sandwiched
FSC	Forest Stewardship Council
FSC	Forest Stewardship Council
GBCI	Green Business Certification Incorporation
GBI	The Green Building Initiative Administers the Organization
HERS	Home Energy Rating System
HRV	Heat Recovery Ventilator
HVAC	Heating, Ventilation, And Air Conditioning
IAQ	Indoor Air Quality
ICPs	Insulated Concrete Panels
IEQ	Indoor Environmental Quality
IGU	Insulated Glass Unit
IRC	The Internal Revenue Code (Energy Code)
LBC	The Living Building Challenge
LCA	Life Cycle Assessment

LEED	Leadership In Energy and Environmental Design
Low-E	Low Emissivity
MSDS	Material Safety Data Sheet
NO2	Nitrogen Dioxide
NUAF	Non-Urea-Added Formaldehyde
OSB	Oriented Strand Board
POU	Point-Of-Use
PV	Photovoltaic
RESNET	Residential Energy Services Network
SCMs	Supplemental Cementitious Materials
SHGC	Solar Heat Gain Coefficient
SIPs	Structural Insulated Panels
UN	The United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDESA	The United Nations Department of Economic and Social Affairs
UNHSP	United Nations Human Settlements Programmer
VOCs	Volatile Organic Compounds
VRV	Variable Refrigerant Volume

Chapter 1

INTRODUCTION

1.1 Research Background

The history of kitchens as a topic is an interesting one, shedding light on the development of human society and our connection to food; Kitchens throughout time have undergone major changes in structure and cultural relevance (Hadley Keller, 2016).

Fire influenced the transformation from nomadic lifestyles to settled communities. Fire also came into use as heating source thereby changing eating habits and food storage practices. In old civilizations like the Assyrians, Phoenicians, Egyptians, Persians, Greeks and Romans, grandiose banquets were common events. However, gradually cooking ceased being a joint effort and moved away into its own room; kitchen. Research on efficiency during twentieth century gave importance to optimization and built-in kitchens emerged as well. The electrical grid introduced labor-saving devices that cut down on cooking time in kitchens. Such advancements affected mainly the upper-middle class hence exposing social disparities that exist with regard to how modern kitchens are planned and fitted (Giovana Martino, 2022).

Kitchens have been integral to culinary and cultural traditions throughout history. Buying, preparing, cooking, serving, dining in or out of doors (in some cultures), securing and storing food are some activities that have revolved around kitchen life.

Various objects such as gadgets or utensils for cooking or serving foods; plates; embellishments; furniture pieces belonging to this place have all contributed towards what makes a good kitchen work well or not at all. This diverse range of kitchen activities ranging from work-play-homemaking-customer service-entertaining has affected how kitchens are designed and composed in terms of their functionality (Snodgrass, 2004).

The kitchen is one of the most functional parts of a house and therefore, it plays a crucial part in the sustainability of houses. The functionality of contemporary kitchens is not simply summarized in cooking. Today a kitchen is the place for dining, food storage, washing clothes, and sometimes for leisure. The aforementioned multifunctionality of today's kitchens has led designers to have difficult task in order to design a satisfactory kitchen for customers. The complexity of modern kitchens' multifunctionality along with considerable expenses of kitchens' parts create additional importance for modern kitchens in architectural projects (Atamewan, E.E., & Otu, E. (2018).

Environmental consciousness has grown drastically among consumers leading to an increase in demand of green buildings (Li et al., 2021). There are studies reporting that consumers will pay higher prices for green buildings (Fuerst & McAllister, 2009; Juan et al., 2017; Tsai., 2022). However, the implementation of green building concept in infrastructure of cities has faced difficulties due to unattractive return of investment and high complexity in promoting green building idea (Bungau et al., 2022).

1.2 Problem Statement

One of the places in houses that can impact sustainability significantly is kitchen due to including various gadgets and devices as well as many residential tasks. To design a sustainable kitchen is a complicated task and designers should consider a lot of factors to achieve this goal. Despite this fact, to the authors' best knowledge, no study has attempted to develop a guideline for designers to design sustainable residential kitchens. The articles on sustainable kitchens are scarce and more related to smart kitchens concerning IT and digital solutions. (ArchiExpo E-Magazine. (2024, February 19). There is a significant lack of integration in architectural literature to make sustainable guideline applicable for interior designers. Therefore, this study is interested in creating a comprehensive guide regarding sustainable interior design of residential kitchens.

1.3 Research Questions

This research is an attempt to find scientific answers to the following main research question:

"What can be done by interior designers in order to design a residential sustainable kitchen? What are the practical solutions for designing a sustainable residential kitchen?"

In order to answer the main research question, the following sub-questions have been devised:

- What are the main characteristics of the sustainable interior design?
- What is a eco friendly sustainable residential kitchen?

1.4 Aims and Objectives

This research aims to review literature on sustainable residential kitchen design comprehensively in order to develop an integrated sustainable guideline for residential kitchen design. Therefore, the following research objectives are devised:

A comprehensive literature review for defining sustainable interior Architecture,

Development of a practical guideline for designing sustainable residential kitchens including comprehensive set of practices and instructions appropriate for interior designers to follow.

1.5 Significance of the Study

The findings of this study can contribute to the literature by filling the gap between sustainable practices applicable to kitchen design and architectural literature. In addition, this study would benefit the practitioners as well as architectural academia by presenting feasible sustainable pathways for kitchen design through a comprehensive and integrated sustainable guideline.

1.6 Research Methodology

In order to achieve aforementioned research objectives, this study employs a qualitative research design including literature review. Literature review method enables this research to collect the most relevant data in order to develop its desired guideline in terms of sustainable interior design and sustainable residential kitchen design. The literature review make it possible for this study to identify and summarize the current state of knowledge on the topic of interest. The reviewed academic content enables this research to recognize key concepts related to research topic. Organizing and synthesizing the literature have led this study into coherent themes and patterns making it possible to provide practical considerations for interior designers on sustainable residential kitchens.

1.7 Limitations of the Study

Although sustainability is a three-faceted concept (Social, Economic and Environmental) and for a truly sustainable design all these aspects should be considered simultaneously, due to existing limitations for conducting this study, and because interior designers are mostly engaged with environmental aspect of this matter, this research mentions Social and Economic aspects of sustainability, however, the main focus of this study is on the environmental aspect of sustainable interior design of residential kitchens.

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Chapter 2

SUSTAINABLE INTERIOR ARCHITECTURE

This chapter aims to define sustainable interior design through answering the following questions:

- What is sustainability and how is it related to interior design?
- What are the main criteria of sustainable interior design according to literature to date?

First, this chapter explains that what was the underlying reasons for creation of sustainability concept. Second, the notion of sustainable architecture is described through literature review and providing prominent examples. Further, the challenges ahead of sustainable architecture are introduced. Thirdly, sustainable interior design is elaborated through different frameworks and its main criteria and goals are introduced. Fourth, a conclusive explanation is provided to describe how interior designers should think about their profession in order to contribute to global concerns in terms of sustainability.

2.1 Sustainability

Many movements emerged from social justice environmentalism (seeks to reorient the environmental concerns and goals towards justice and equity), internationalism (encourage political and economic cooperations at global level) and global warming have led to a growing interest in sustainability. Consequently, it requires environmental conservation, social responsibility and society that has a balance

between human and natural systems. Now there are global societal concerns related to the environment, society and the economy. As a result of this, scholars and practitioners are currently more aware about what sustainability means. Basically, sustainability can be defined as procedures or activities that lessen the possibility of diminishing natural resource availability and maintaining ecological balance globally. Sustainability is now an important concept for all industries including; textiles; agriculture; urbanization; infrastructure development; water supply systems; energy consumption rates and transport sectors (Hashim et al., 2023).

Cities have experienced a significant population increase globally since the industrial revolution. These urban areas draw many families, skilled, and unskilled workers who are looking for better job opportunities, a higher standard of living, quality life, education and infrastructure as well as sustainable transportation among other things. Urbanization increased first in some of the major megacities in America, Europe, Africa and Asia. The overpopulation of cities has resulted in resource depletion, biodiversity loss, deforestation, water pollution and climate change. The aforementioned problems yielded to the development of a concept called “sustainable city” (Hashim et al., 2023).

For example, an eco-city is a city that has three main pillars of which include social development, environmental management and economic growth. In 2002 at the United Nations Human Settlements Programme (UNHSP) headquarters in Nairobi, Kenya where World Urban Forum was held it was believed that sustainable urbanization should concentrate on social, environmental and economic development besides urban administration. As such, urban governance should be founded on social,

environmental and economic development. It's through this way a city can assure itself of its sustainability. (Hashim et al., 2023).

Figure1shows the World urbanization prospects on sustainable cities developed in United Nations Department of Economic and Social Affairs (UNDESA) in 2012. Interior designers can contribute significantly to sustainable cities by incorporating these perspectives in their profession. Interiors should be the place of social development, which improves economy, sustain planet and provides pathways to sustainable governance and infra-structures.

Figure 1: Un/desa, development policy and analysis division.

Sustainability has been one of the most influential social movements over the last forty years. However, sustainability is defined differently by different people due to its multiple uses. The release of the Brundtland Report by The United Nations (UN) in 1987 made sustainability famous as an issue for scientific study and social research which consequently resulted in various definitions of this term (Brinkmann, 2022).

Sustainability is explained by Wühle (2023) who says recent definition of sustainability was shaped at the end of twentieth century, predicated upon three dimensions specified in what was labeled as Brundtland Report:

- Ecological sustainability: It is built on Carlowitz's ideas, a German mining manager, and primarily focuses on the simple notion of not abusing the natural world. Sustainable living only consumes renewable natural resources.
- Economic sustainability: A society should not live beyond its means because that would mean losses to the posterity. An economic system is considered sustainable if it can operate indefinitely.
- Social sustainability: The organization of a community or a state should ensure that social tensions are kept at a manageable level and differences resolved in an amicable manner without escalating into violence.

The main purpose of the field is to start acting now to ensure that future generations can succeed and have resources. To guarantee a bright future for next generations, sustainability concerns environmental, economic, and equity issues which are known as 3 E's. In comparison with the environmental movement, this discipline encompasses matters related to economics and social equality much more extensively (Brinkmann, 2022).

However, sustainability is somewhat disjointed at present. In developed countries, the concept of sustainable development often emphasizes minor changes in long-standing behavioral patterns rather than radical alteration of societies. For example, electric cars, and a ban on the use of plastic bags do not reduce the high levels of consumption that are the causes of the unsustainable patterns in the West. However, it is the poor

countries that are trapped in their own situations such as, lack of clean water among other barriers that sustainable development aims to make better (Brinkmann, 2022).

Electric vehicles are not fully sustainable at the moment. The limited resources of lithium, unsustainable generation of electricity, significant carbon footprint of materials used in electric vehicles are examples of issues with the sustainability of these cars. Plastic bans cannot be effective alone. There are unattractive alternatives to plastic which have more unsustainable production process (e.g. fabric bags) and are less hygienic. In addition, there are many jobs and industries profiting from plastics which yields to political and economic challenges for banning plastic worldwide. The aforementioned examples show that effective sustainable changes require a multi-aspect solution covering social, economic, environmental and governmental sides. This insight is aligned with the world urbanization prospects depicted in figure 1.

2.2 Sustainable Architecture

Sustainable architecture seeks to minimize negative environmental impacts through improved efficiency and moderation in the use of materials, energy, development space, and the ecosystem at large (Sassi, 2006).

Hohenadel (2024) states that the term "sustainable architecture" refers to all buildings that have been constructed to have less of an effect on the environment. A building that is designed and built in a way that does the least amount of harm to people's health and the environment is called "sustainable architecture. (Page 156.)". A building that is designed to last is important because it uses a lot less water and energy over time and is made with fewer chemicals that are harmful to the environment. Bowen (cited in Hohenadel (2024) explained that sustainable architecture is a type of architecture

that focuses on being environmentally friendly in every step of the planning and building process. To be sustainable, architecture must use its materials, methods, and systems in ways that lessen its effect on the environment of the future while still meeting the needs of the people who live there now. According to Usanga (2024), which cites Tadao Ando (2012), it is important to include certain building parts in the architectural design. Building elements that can be used in architectural design to make the best use of the building's relationship with the landscape around it.

Incorporating each stage of planning and construction in modern-day buildings this approach encompasses eco-friendly building design methods including choice of building materials; planning for heating, cooling plumbing, waste management and air conditioning systems among others; fitting man-made structures into natural landscapes (Guy & Farmer, 2001).

Healthy living spaces are created by sustainable architecture aiming at reducing environmental degradation as well as energy consumption and human resources utilization. Sustainable architecture has emerged as a solution to minimize carbon footprint of buildings from procurement and construction phase to operation and maintenance phase (Pal et al., 2017).

Building materials used reflect sustainable architectures as well as general designs for example resource use. Moreover, during building life cycle this design should also ensure that it is capable to be operated sustainably up to disposal level while keeping a long-term energy saving goal and resource efficiency beyond being functional and aesthetically superior (Hegger et al., 2012).

There are various examples globally which reflect sustainability in architectural designs through use of innovative designs combined with eco-friendly materials. Some examples of sustainable architecture include:

- Sanko Headquarters: located in Istanbul Turkey has a green roof designed to reduce solar radiation while having an atrium void for natural light hence minimizing electricity consumption (Korumaz & Korumaz, 2012).

Figure 2:Sanko headquarters: located in istanbul turkey (URL1)

- Beitou Public Library: situated in Taipei Taiwan comprises solar panels that stores power up to 16W making it the first green library in Taiwan (Tseng, 2008).

Figure 3:Beitou public library: situated in taipei taiwan (URL 2)

- Bullitt Center: found in Seattle USA referred to as world's greenest commercial structure incorporates net-zero energy, net-zero water and carbon, composting toilets, toxic-free materials, and 80% daylighting (Homchick Crowe, 2020).

Figure 4:Bullitt center: found in seattle usa (URL 3)

- Manitoba Hydro Place: situated in Winnipeg Canada uses water from Guanabara Bay to cool the building and fills the surrounding reflecting pools, also it has mobile Photovoltaic (PV) solar panels (Robb & Fitzpatrick, 2020).

Figure 5:Manitoba hydro place: situated in winnipeg canada (URL 4)

- Vertical Forest: located in Milan, Italy is a residential building with a plant-based facade that does not reflect sunlight thus reducing the heat island effect (Ishween, 2021).

Figure 6:Vertical forest: located in milan, italy is a residential building (URL 5)

- Pixel Building: found in Melbourne Australia became the first carbon-neutral office structure there generating on-site power and water while its windows are fitted with colorful panels for shading and letting more light inside (Rogers, 2013).

Figure 7:Pixel building: found in melbourne australia became the first carbon-neutral (URL 6)

- One Central Park: situated in Sydney Australia is a residential building which has a skin made of solar panels while temperature regulation involves pumping warmer and cooler water between different levels of an aquifer (Narwal, 2022).

Figure 8:One central park: situated in sydney australia is a residential building (URL 7)

- The Edge: based in Amsterdam Netherlands having 98.3% sustainability score according to British rating agency BREEAM this remarkable building incorporates rainwater capturing roof as well as vertical wind turbines for energy saving purpose (Charlesworth & Adams, 2013).

Figure 9:The edge: based in amsterdam netherlands (URL 8)

- Parkroyal Collection Pickering: positioned in Singapore it is a hotel design that conforms to Singapore's Landscape Replacement Policy that requires equal public green space for every piece removed during development (Hudson, 2020).

Figure 10:Parkroyal collection pickering: positioned in singapore (URL 9)

In various areas of architecture, such as energy efficiency, water conservation, waste management, and the use of innovative materials and technologies in construction, the

aforementioned examples illustrate the implementation of sustainable design principles.

There are several challenges ahead of sustainable architecture, which include:

- Cost: Sustainable architecture often requires more expensive materials and technologies making it more costly to build and operate. This can be a barrier for many developers and homeowners who may be more concerned with the upfront costs rather than the long-term savings (Hayles & Kooloos, 2005).
- Limited availability of sustainable materials and technologies: Many sustainable materials and technology have not fully developed or are less durable compared to conventional ones hence difficult to incorporate by architects into their projects (Bredenoord, 2017).
- Preconceived notions: Many people think that sustainability is only a word that is hard to apply in projects making it difficult for architects to sell their designs to clients who may be more preoccupied with aesthetics rather than sustainability (Johnson, 2012).
- Building regulations: Official building codes encourage unsustainable means of architecture and construction thus lack heat insulation while promoting artificial cooling. In order to support sustainability; these official policies should be remodeled (Zhang et al., 2019).
- Quantifying sustainability: It is difficult to quantify how much good a green practice does for an environment on a project – scale making it harder to convince clients about its importance (Smith, 2010).
- Limited scope: Sustainable architecture entails designing and constructing energy-efficient, resource-efficient, and environmentally friendly buildings but

> it does not address all other environmental issues associated with the built environment. In fact, this will only be possible if we fundamentally change how we design, build and use buildings on a large scale addressing environmental challenges facing the world today (Kibert, 2016).

Despite these challenges however, sustainable architecture is gaining momentum becoming more accessible due to innovation in materials and technologies mentioned above (Bielek, 2016).

2.3 Sustainable Interior Architecture

Sustainability as a concept and sustainable design as an approach should not be limited to prescriptive environmental rules and regulations. An appropriate approach of sustainable design should be able to explore interconnections and interdependences between three components of sustainability in order to fulfill all the stakeholders' interests and consequently become a sustainable solution in long run. A sustainable design not only should be able to protect the planet, but also should contribute to economics and yield social responsibility. The figure 11 depicts the comprehensive framework of sustainable interior design based on triple bottom line concept (Lee, 2014).

Sustainability is all about the environment and human welfare. When it comes to building development and repair, interior design takes a big swing at both. Green construction practices rely heavily on this aspect of building, which is why interior design is considered sustainable. The materials, goods, and systems used in a building's interior play a massive role in how we consume energy and resources. Beyond that, sustainable interior designs need to have their interconnections and

implications taken into consideration. Interior designers should work collaboratively with integrated design systems to lessen these consequences as much as possible. Clients and rating systems will be good for guidance as well. Efforts are being made to create houses with sustainable interiors but there are three main things standing in the way: cost, material, and education (Reham & Eldin, 2017).

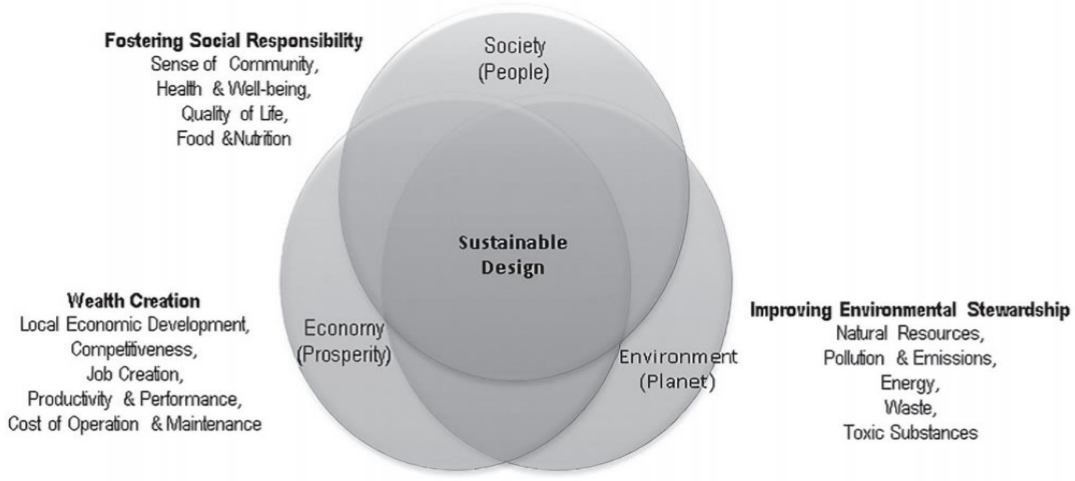

Figure 11: The comprehensive framework of sustainable interior design based on triple bottom line concept (Lee, 2014).

Lee (2014) introduces the sustainable interior design framework as a system combining integration of processes related to building industry with the concept of knowledge creation theory. In order to integrate the process of sustainable interior design, three types of communities should collaborate:

A: The owner and local community;

B: The design practitioner community including interior designers, architects and landscape architects;

C: The other built environment discipline community (engineers, specialty consultants and contractors).

These three communities should collaborate and share knowledge with each other in every step of design process. These practices enable integration of design process to maximize the creation of feasible and beneficial solutions to optimize sustainability of the design projects. The integration process in not linear and it has a repeating pattern of research and analysis. Figure 12 illustrates the integrated process of sustainable design with involvement of the main communities. Figure 13 demonstrates the involvement of main communities in sustainable design throughout different stages of the project.

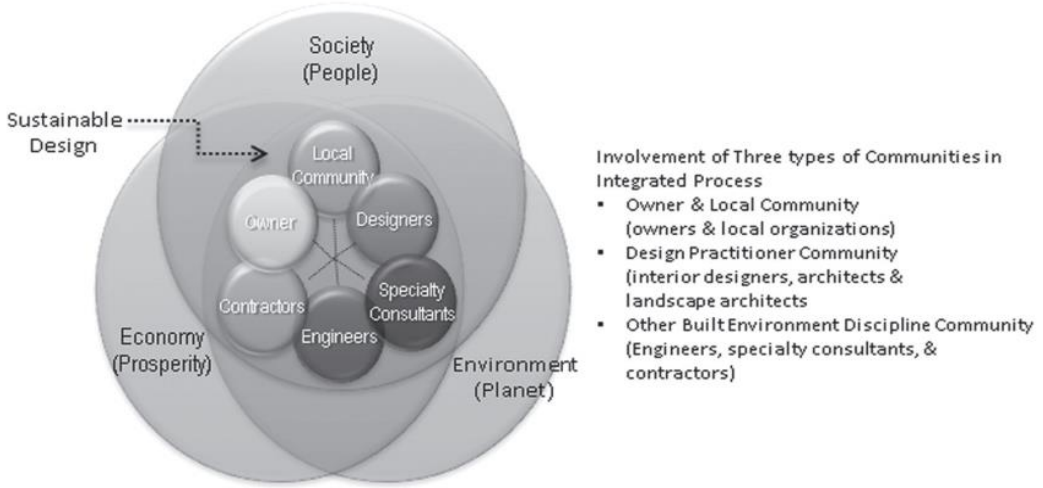

Figure 12: Involvement of three types of communities in integrated process (Lee, 2014 page 5).

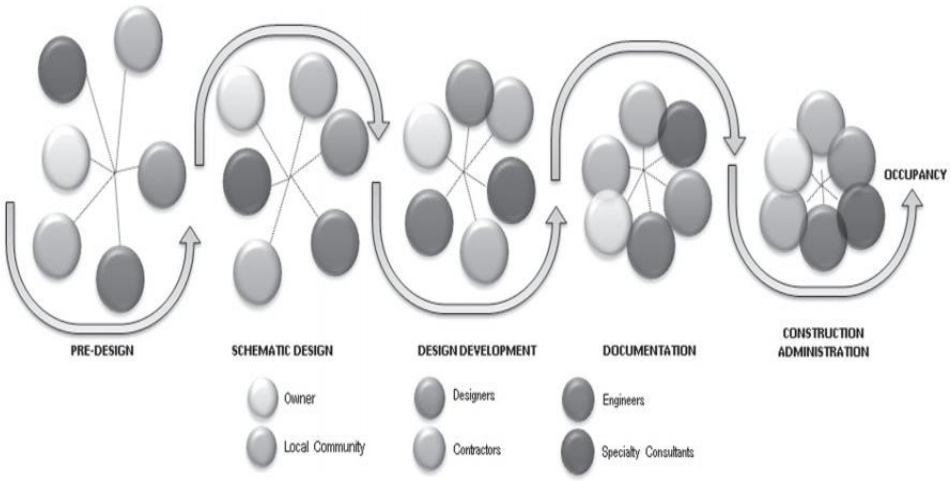

Figure 13: The involvement of main communities in sustainable design throughout different stages of the project (Lee, 2014,page 6).

Interior designers should propose and specify environmentally safe products for every job they take on. Net-zero-energy interiors can only happen when we start challenging our talents. This means exploring new ways to further improve energy efficiency within our designs. Designers should also encourage staff to adopt these practices as consistently as possible. There are many factors that can help responsible interior designers choose sustainable solutions for their projects. Rashdan's five criteria include manufacturer selection, health benefits, decreased consumption rates, maintenance sustainability rate/design components and effective resource management (Rashdan & Ashour, 2017). It's important to find balance within all of these criteria evaluating all pros, cons and benefits this decision will bring to achieve project goals successfully (Rashdan & Ashour, 2017).

Knowledge creation is the other pillar of Lee's (2014) sustainable interior design framework besides integrated process. Knowledge is defined as relevant information processed by experience, context, meanings and ideas. In order to generate knowledge in interior design projects, adaptive process of knowledge creation should be applied

instead of employing prescriptive knowledge. The adaptive knowledge is created through four modes:

A) Socialization: is about sharing tacit knowledge experienced directly by individuals;
B) Externalization: is about the process of converting tacit knowledge to explicit through dialogue including articulation and translation of experiences and ideas;
C) Combination: is the process of combination of documented and processed knowledge in order to create systematic explicit knowledge;
D) Internalization: is the process of converting explicit knowledge to tacit knowledge through applying the explicit knowledge to real-world problems.

The process of adaptive knowledge creation comprising of the aforementioned four modes are not linear or circular. This process is progressive and evolving in which transcendence of experience and knowledge is possible. The process of conversion between tacit and explicit knowledge consists of five phases: “sharing tacit knowledge, creating concepts, justifying concepts, building on archetype and cross-leveling knowledge”. Figure 14 shows the four modes and five phases of knowledge conversion applied to interior design process.

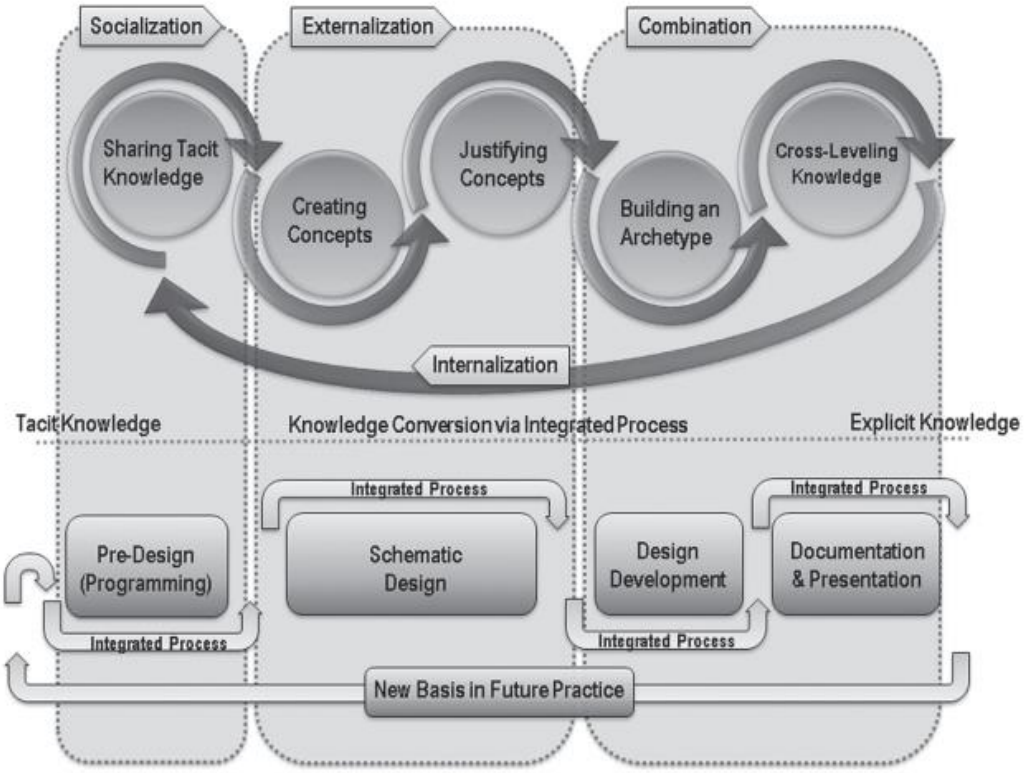

Figure 14: The four modes and five phases of knowledge conversion applied to interior design process (Lee, 2014,page 7).

Flexibility is the key to improve the efficiency of interior design in terms of sustainability. There's a lot of practical and form options in interior design flexibility. This quality is used to make spaces more livable and convenient for its occupants, as well as reducing reverse migration. In the design process, it's important to maximize horizontal space with good furniture design and structure, think about floor flexibility, as well as think of ways to allow mobility and growth. New techniques in furniture manufacturing also help preserve interior space by promoting self-sufficiency. It makes major spaces in cities scalable. These designs prioritize sustainability criteria like capacity, fitness, resilience, diversity and balance (Abdulpader, Sabah & Abdullah, 2014).

We all know that technology does not stop developing and growing, sometimes to our benefit or not. Technological advancements have a significant impact on our general well-being and how we use architectural spaces. Professional career in Interior Designing is increasingly difficult due to the new learning curves it adds everyday – merging creativity, aesthetics innovation and practicality. This pragmatic approach helped improve the building's convenience through smart home technology. Research has shown that “flexibility” and “sustainability” are sometimes used interchangeably when discussing similar things. Developing space flexibility is a key strategy to create sustainable usage of areas - it is an effective way of using available space too. The kitchen is traditionally the meeting place in a house Kitchen tables may serve multiple purposes aside from cooking. it can create a welcoming and friendly cooking environment for those involved. Smart home concepts try to create an open kitchen without physical boundaries so they can multitask virtual activities with social communication or even job-related activities while still having family gatherings (Al Khafaji & Kamaran, 2019).

Many studies emphasize the ecological sustainability as the main concern of sustainable interior design (e.g., Celadyn, 2018, 2019; Crane, 2008; Demirkan & Afacan, 2018; Platowicz, 2015). However, these studies mention that sustainable interior design should also be aligned with the principals of social and economic sustainability.

Celadyn (2018) explains that interior designers should be environmentally responsible and should activate the environmental benefits of indoor spaces throughout the different phases of design. Sustainable interior design should include the assessment of environmental impact of utilized materials and products as well as the establishment

of resource management with the aim of ecological efficiency. In addition, sustainable interior design should follow pathways in order to improve the quality of indoor environments and enhance the building's performance.

Celadyn (2018) introduces two sequential model for applying sustainability into indoor spaces. The first model is for "Environmental Contextualization of Interior Components". This model can be used to develop strategies in order to exploit resources and environment in sustainable manner. Peer-reviewed studies can be assigned as the foundation of sustainable solutions for indoor spaces with the aim of reducing consumption of resources and improving the quality of interior environments. Figure 15 illustrates the model for "Environmental Contextualization of Interior Components". According to this model, four types of necessary adjustments that should be applied to interior design methodology are:

A) Integrative interior design: is about employing different experts in the process of decision-making for sustainable interior design.
B) Interdisciplinary design platform: The design process should be based on an interdisciplinary platform enabling architects, representative, engineers and consultants to share their knowledge and interests.
C) Evidence-based interior design: Different involved professionals should propose plans based on evidences with the aim of performance optimization in design projects.
D) Research-based assessment tools: Building certification system guidelines based on parametric assessments should be used as a tool for evaluation of sustainability in design projects. Celadyn (2018)

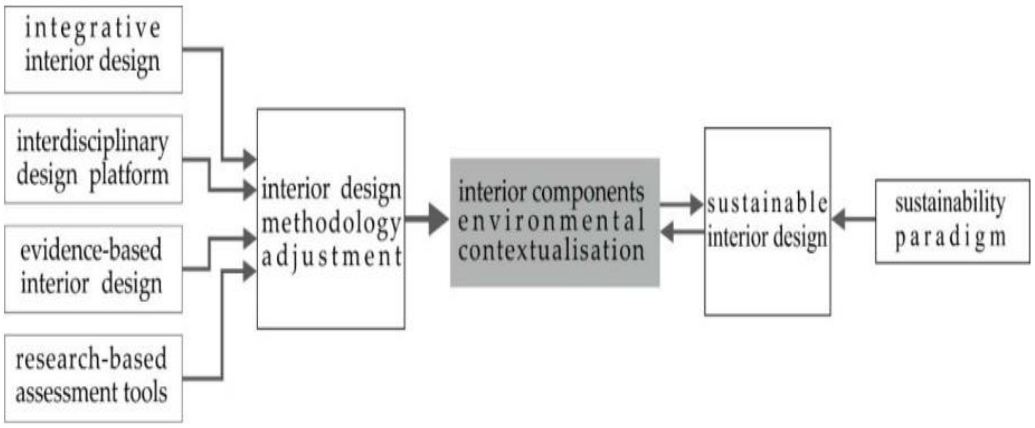

Figure 15: The model for environmental contextualization of interior components (Celadyn, 2018).

The second model proposed by Celadyn (2018) is for "Environmental Activation of Interior Components". This model integrates and explains the vital considerations that should be taken in order to bring effectiveness to environmental contextualization. These considerations are essential for fostering social, economic and environmental sustainability in design projects. The "multi-functionality of interior components combined with the adaptability of inner spaces to accommodate different activities" and appropriate resources management framework are the main aspects affecting the effectiveness of environmental contextualization in sustainable interior design. He also states that Modern interior design should incorporate traditional pillars of interior design (aesthetics, functionality, formality) with the concept of sustainability. Interior designers should consider the connections between built and natural environments and further analyze the direct and indirect relations of these environments scientifically. The underlying strategy of sustainable interior design should respond to occupants needs in terms of comfort and health, while minimizing the environmental impact of building mechanical systems through energy optimization. The combination of resource management, multi-functional thinking, environmental quality control and diversification of spaces should be considered in the environmental activation strategy

in sustainable interior design. Figure 16 demonstrates the model for "Environmental Activation of Interior Components"

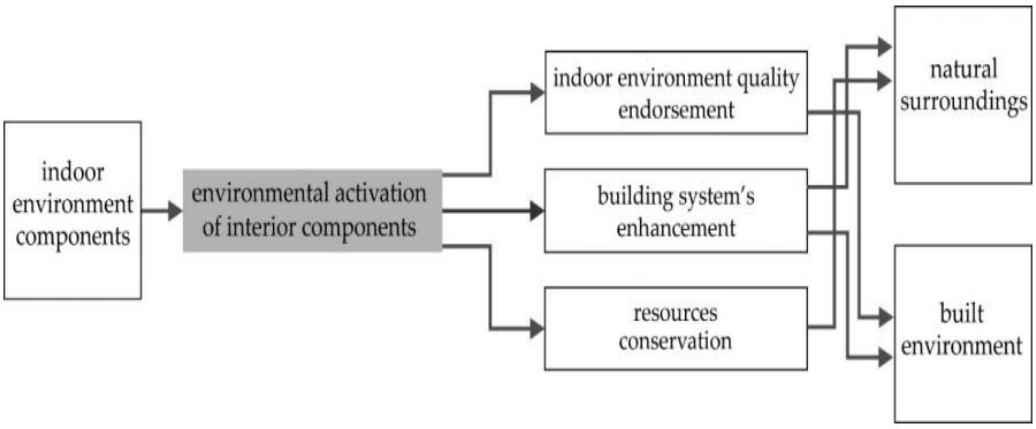

Figure 16: The model for environmental activation of interior components (Celadyn, 2018).

2.3.1 Sustainable Standards and Certification Systems related to Interior Design

green certifications can be divided in two main categories of green certifications for products and green certifications for buildings. Certifying products as green is meant to describe and verify that they meet a given need and provide an environmental advantage. Numerous product labeling and certification programs are known as multi-attribute programs because they certify items based on life-cycle attributes, including water and air pollutants from use, disposal, and manufacturing; energy consumption; recycled content; and more. Some focus on a single attribute, such as emissions of chemicals, water, or energy that affect Indoor Environmental Quality (IEQ) (Vierra, 2016).

Integrated design is necessary for all green building rating systems if projects are to be resource and environmentally responsible at each stage of the building's life cycle — from siting through design, construction, operation, maintenance, renovation, and

demolition. Some of these systems are multi-attribute, meaning they cover emissions, toxicity, overall environmental performance (in addition to water and energy), while some are single-attribute — focusing only on water or only on energy. Regardless of philosophy, methodology or certification process differences between them all — lessening the total impact of the built environment on the natural environment and human health is achieved through awarding or certifying projects (Reeder, 2010).

Green building rating systems exist for every project type — single-family homes to commercial buildings to entire neighborhoods — in both new construction or existing buildings. The former system focuses on decisions made during planning and design along with actions taken throughout construction. For existing buildings, it shifts focus onto operations and maintenance throughout its life. The need for more precise definition/application/measurement of green initiatives along with their results/impacts is one key driver behind the development of rating systems (Espinoza, Buehlmann & Smith, 2012). Figure 17 demonstrates , the most prominent certification systems related to interior space design.

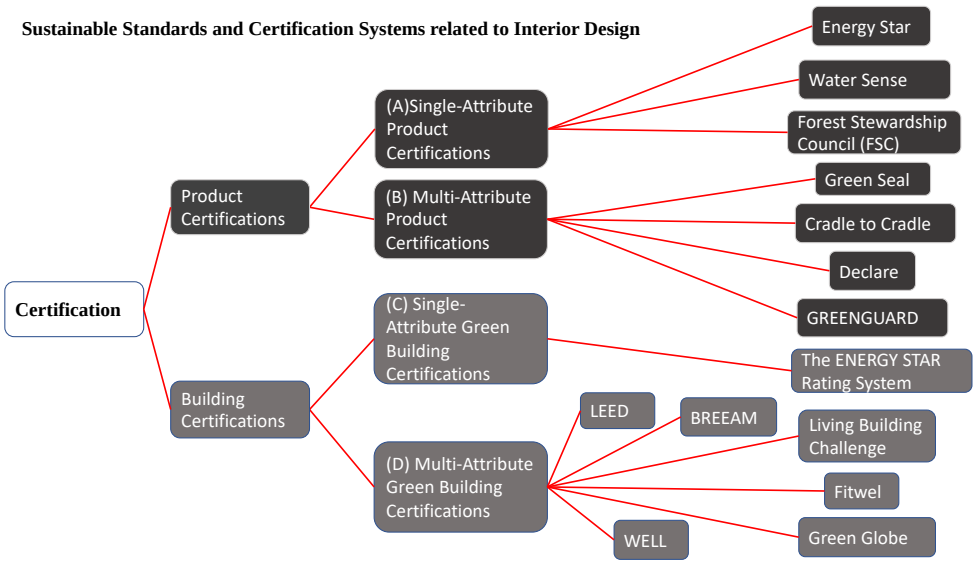

Figure 17:The most prominent certification systems related to interior space design- prepared by the author

In the following text, the important certification systems of aforementioned categories are described:

(A)Single-Attribute Product Certifications

Energy Star

The [Energy Star] label is a certification program for identifying and promoting energy-efficient products and buildings. The [Energy Star] label shows that products meet strict efficiency criteria set by the U.S. Environmental Protection Agency (EPA). For example, qualified refrigerators must be at least 15% more efficient than the federal minimum standard, and qualified light bulbs (CFLs) must use two-thirds less energy than a standard incandescent bulb. Similarly, commercial buildings must earn an [Energy Star] score of 75 or higher out of 100 to be eligible for certification. By using less energy, certified products help consumers and businesses save money on energy bills while also reducing greenhouse gas emissions (ENERGY STAR, 2024; Brolinson, Palmer & Walls, 2023)

WaterSense

WaterSense is a voluntary partnership program sponsored by EPA that provides a label for water-efficient products and serves as a resource for saving water. Products with the WaterSense label are certified to use at least 20% less water, save energy, and perform as well as or better than regular models. The program partners with manufacturers, retailers, homebuilders, and other organizations to promote water efficiency and conservation. To earn the WaterSense label, products undergo independent third-party testing to ensure they meet EPA's criteria for efficiency and performance (Schein , Bickmore & Sovocool, 2022; WaterSense, 2024) .

Forest Stewardship Council (FSC)

The Forest Stewardship Council (FSC)] certification ensures that products come from responsibly managed forests that provide environmental, social, and economic benefits. There are two types of FSC certification: Forest Management Certification confirms that a specific area of forest is being managed in line with FSC standards; [Chain of Custody Certification] traces the path of products from forests through supply chains. FSC-certified wood is one of many environmentally preferable choices available for green building projects. Indeed it stands as the most specified green-building product in various databases (Sugiura & Oki, 2018; FSC, 2024).

(B) Multi-Attribute Product Certifications

Green Seal

Green Seal certification ensures that a product or service meets health-based standards developed by Green Seal; it does not certify buildings themselves. Any life-cycle stage may be certified, including design, construction, and operations. Green Seal is a global nonprofit organization that has been in the ecolabeling business for more than 30 years.

It claims to have developed hundreds of environmental leadership standards that help ensure when a product or service is awarded the Green Seal certification mark, it has proven itself to be environmentally preferable. If a product or service meets Green Seal's criteria it will bear the Green Seal certification mark which is recognized by consumers as representing environmental and health leadership (Beerling & Sahota, 2013; Green Seal, 2024).

Cradle to Cradle

The Cradle to Cradle (C2C) certification is the world's most rigorous multi-attribute standard for assessing and certifying products based on their environmental and social performance. C2C offers a continuous improvement path, evaluating products in five critical sustainability/quality areas: material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness. C2C certification challenges companies to make products that are safe for people and the environment while also being circular — designed to be made again and again without losing value. It pushes manufacturers to do better by requiring constant progress in building circularity into operations; protecting air, water, and soil; stewarding climate change; promoting equity; making safety a prerequisite; designing with intention; creating value with clean ingredients; aiming higher for human health; using the wisdom of nature as inspiration; creating more good instead of less bad; and embracing diversity. Administered by the Cradle to Cradle Products Innovation Institute, the program recognizes companies that are designing products or processes that work more like natural systems — minimizing negative impacts instead of just reducing them — so they can leave a positive ecological footprint. Companies that want C2C certification must work with qualified independent assessment bodies to ensure their product meets the requirements laid out by Cradle to Cradle Products Innovation

Institute (C2CPII). Since its launch in 2005, over 700 organizations from more than 40 countries have achieved the Cradle to Cradle certification (C2C, 2024; Niero, Olsen & Laurent, 2018). Figure 18 demonstrates the Cradle to Cradle Certified® (C2C) Product Standard. The Cradle to Cradle accreditation is an internationally acknowledged standard used to assess the safety and sustainability of items designed for the circular economy.

Figure 18:Cradle to cradle certified® (c2c) product standard

GREENGUARD

A GREENGUARD certification, especially at a Gold level, basically means that the product is free from dangerous chemicals. It's to reduce air pollution and keep people safe from breathing in anything that might hurt them. This is especially important for kids, who spend most of their time indoors. Over 10,000 chemicals are tested, as well as Volatile organic compounds (VOCs) emissions. In order for manufacturers to

maintain good indoor air quality, they have to meet high standards that prevent chemical gases from being released into the building. Products with a GREENGUARD Gold Certification release little to no gases that can contaminate indoor air (Vierra, 2016). While the author discussed the house's inside, they omitted any mention of the kitchen area.

This certification does not assess the presence of substances such as lead or flame retardants. Therefore, the presence of this mark on a product does not guarantee its total safety. To ensure the safety of a product, it is necessary to examine both the chemical composition information and the certification label. These examples include Building materials, furniture, furnishings, electronic equipment, cleaning and maintenance products and Medical devices for breathing gas (GREENGUARD, 2024). Take into consideration that it may not be assessed inside or in the kitchen;

- Building materials
- Furniture
- Furnishings
- Electronic equipment
- Cleaning and maintenance products
- Medical devices for breathing gas (figure 19) (GREENGUARD, 2024).

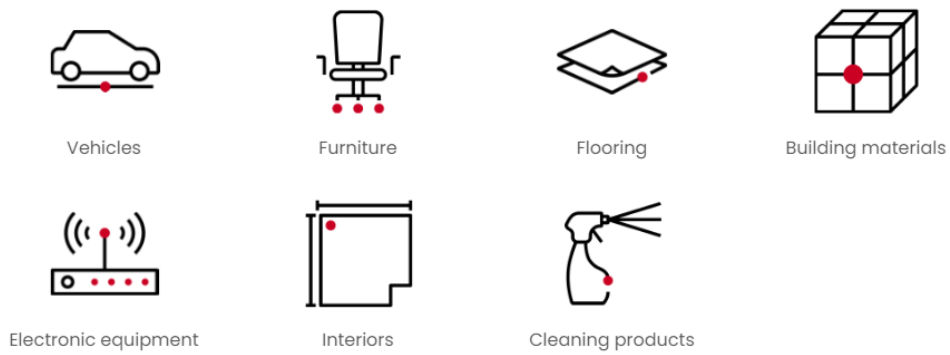

Figure 19:Examples that the greenguard certification scrutinizes (Vierra, 2016).

Declare

The Declare certification], offered by [the International Living Future Institute], evaluates products according to their compliance with the "Imperatives" within the [Living Building Challenge 4.0 standard]. It provides a platform for manufacturers to voluntarily disclose product information on easy-to-read [Declare] labels, which are accessible on a free database used by designers, real estate owners, and homeowners to specify trusted healthy building products. To rise above greenwash and gain market access in green buildings, users can certify “Red List Free” or “Declared”. Third-party verification confirms ingredients and supply chain transparency with specifiers. Certifications align with Core Green Building (LEED) and WELL Certifications (Declare, 2024).

(C) Single-Attribute Green Building Certifications

The energy star rating system

The ENERGY STAR Rating System] essentially tells you how energy-efficient a building is. Buildings that earn the certification score 75 or higher on the [ENERGY STAR] scale, which means they are built better than at least 75% of similar buildings. These scores are verified by an independent company. The program provides tools and resources to help organizations evaluate their energy performance. In order to get certified, a building must submit complete energy use details into the Portfolio Manager tool. The data must cover a minimum of 12 consecutive months, and be verified and stamped with an engineer or architect’s license number. Once approved, the building can enjoy financial benefits from its environmental benefits (ENERGY STAR, 2024; Brolinson, Palmer & Walls, 2023).

(D) Multi-Attribute Green Building Certifications

BREEAM

BREEAM (Building Research Establishment Environmental Assessment Method)] is used to rate how green a building is. It evaluates every aspect of its design, construction and operation like transportation pollution, land use and waste reduction. The rating is done by a third party that uses standards created by BRE Group. With this seal of approval on your building, it'll become more attractive to investors looking for sustainable properties because it's proven to have higher sustainability ratings than the average property. It also gets builders closer to certifications like LEED (Cole & Jose Valdebenito, 2013; Giama & Papadopoulos, 2012).

LEED

Certification for the Leadership in Energy and Environmental Design (LEED) is a recognizable symbol of sustainability achievement in green buildings. It offers a framework to create healthy, highly efficient, and cost-saving buildings that deliver environmental, social, and governance benefits. Certification is based on points with four levels: Certified, Silver, Gold and Platinum. Points are awarded by LEED for various aspects of a building such as CO2 emissions, energy efficiency, water usage, waste management, transportation, materials used in construction and indoor environmental quality. It also encourages project teams to integrate sustainable practices into the design, construction, operation and maintenance of their buildings. Buildings that are certified by LEED are crucial to the fight against climate change because they enhance resilience and support more equitable communities (Kubba, 2009; LEED, 2024).

The mission and vision of LEED can be summarized in the following text extracted from “The future of LEED” describing the principles that guide LEED organization:

“There is incredible responsibility that comes along with developing the LEED green building rating system. How can humanity drastically transform its approach to the buildings and communities where we live, work, learn and play in such a short time?” (LEED, 2024)

Green Globe

Green Globe certification is a rating system for green building that evaluates environmental sustainability against several factors like resilience and effects on occupants’ health. This includes commercial properties such as institutions or residences. The Green Building Initiative administers the organization (GBI) around this system which is an international nonprofit company that improves built environments with hopes of reducing climate impacts. You can earn certification through Green Globes for new constructions or existing ones along with interior spaces which all score differently on a weighted 1-1000 scale assigned by GBI employees who have also been trained by them as well. Some focuses when scoring include water conservation methods organic material selection which helps air quality energy efficiency development planning etc. By getting certified you can prove your building’s commitment to sustainability improve its marketability land cost savings recognize energy efficiency conserve water better indoor air quality expect many other good things (Ásványi, 2021; Green Globe, 2024).

Living building challenge

The Living Building Challenge (LBC) is a green building certification program that goes beyond merely being “less bad” to become truly regenerative. Launched in 2006, the LBC is described as a philosophy, advocacy tool and certification program for measuring sustainability in the built environment. The LBC is organized into seven performance areas: place, materials, water, equity, energy, beauty and health + happiness. To achieve LBC certification, projects must be operational for at least twelve consecutive months prior to audit to verify their actual performance (Zimmermann et al., 2019; LBC, 2024).

Buildings that meet the challenge connect occupants to light, air food nature and community while creating a positive impact on human and natural systems. It can be applied to developments at all scales from buildings to infrastructure landscapes neighborhoods and communities. The LBC is considered one of the most rigorous green building certification programs because it requires projects to produce more clean water and energy than they use and to send less waste to the landfill than was used in building’s salvaged material (Aguacil Moreno, Moreno & Pauwels, 2020; LBC, 2024).

WELL

The WELL Building Standard is a holistic approach that addresses human health and well-being through the built environment. Third party certified by Green Business Certification Incorporation (GBCI) – which also administers the LEED certification program – the WELL Building Standard is managed an administered by International WELL Building Institute (IWBI). It’s a performance-based system for measuring certifying and monitoring features that impact human health in occupancies such as

offices retail education healthcare residential restaurants entertainment sports facilities manufacturing warehouses logistics labs fitness centers hotels among others. Its framework focuses on seven core concepts of health: air water nourishment light fitness comfort mind. All of which seek to create an environment that improves nutrition, fitness, mood, sleep patterns performance and thus overall well-being occupants. There are multiple ways buildings earn points toward WELL certification based on different project types including new construction or major renovation commercial interiors core shell existing buildings operations mechanical platform multifamily residential and neighborhood. One of the main principles behind WELL certification is that no building can be truly sustainable unless it's also healthy (IWBI, 2024; Labartino. 2018)

WELL certification considers not only building design and construction but also operations maintenance occupant behavior and facility management procedures. It's a comprehensive certification that pays attention to all elements of sustainability as it promotes buildings where all parts work together to improve the physical mental and emotional health of the building users. While other green building certifications like LEED focus on environmental and energy standards, the WELL Building certification focuses solely on how the built environment can improve a human's physical mental and emotional well-being. As said above, this includes proper nourishment, exercise, sleep patterns, diversity, community building, promotion of cognitive stimulation and emotional well-being (IWBI, 2024).

Fitwel

Fitwel is a certification process that guarantees the compliance of kitchens and other areas of a building with health standards for all persons. It is based on a survey of 7000

academic articles as well as strategies to build and maintain environments that support the concept of well health. Fitwel may be applied to a number of kitchen initiatives, including domestic and professional cooking spaces and eateries. It however requires some effort to gain the certification but the benefit that comes with it makes it all worth it. Possible and observable improvement include; improvements in the kitchen personnel and the general health, well-being and happiness of the people within the kitchen. The Fitwel certification standards include basic requirements like; air quality, water quality, healthy food options, physical activity, and mental health. To be granted a certification, kitchens must meet the necessary standard as follow (Fitwel, 2024).

2.3.2 Sustainable Interior Design Goals and Criteria

The interior designers should combine the concept of aesthetics and functionality with the aim of fostering sustainability (Ching & Binggeli, 2018). Indoor air quality is one of the main concerns in social health related to indoor spaces (Spengler & Chen, 2000). In order to improve the air quality of interior spaces, interior designers should utilize the materials with the least toxic emissions (Rashdan & Ashour, 2017). Creating healthy environments contributes to human and social aspects of sustainability. In general, sustainability concept can be applied to interior design in order to persuade specific aims. The following goals of sustainable interior design has provided through an extensive literature review:

- Reducing environmental degradation: (Celadyn, 2018, 2019; Crane, 2008; Davis & Fisher, 2015; Demirkan & Afacan, 2018; Platowicz, 2015)
- Improving energy optimization: (Celadyn, 2018; Davis & Fisher, 2015; Kibert, 2016)
- Reducing waste and cost: (Celadyn, 2018; Davis & Fisher, 2015; Kibert, 2016)
- Creating healthy environments: (Alfuraty, 2020)

- Improving the longevity: (Carlsson et al., 2021; Ching & Binggeli, 2018; Matheny,2015; Usal, 2020)
- Improving the multi-functionality: (Fuchs & Brandstätter, 2021; Velkova et al., 2019)
- Increasing the benefits of designed environments: (Davis & Fisher, 2015)
- Increasing environmental awareness: (Kim & Kang, 2022; Kucharczyk-Brus & Żebrowska, 2020)
- Benefiting local industries: (Cao et al., 2022; El Anssary, 2016; Moubarak & Qassem, 2018; Stieg, 2006)

Through an extensive literature review, this study has collected a comprehensive set of criteria for sustainable interior design based on 4 pillars of sustainability (the social aspect of sustainability has divided to social and human aspect in recent literature on sustainability). Table 1 depicts the resulting criteria. The first attempt to create dimensions for sustainability was by Carlowitz who introduced environmental equilibrium, economic security and social justice. The social dimension of sustainability aims to improve and sustain the social capital Carlowitz, H. C. von. (1713). However, by focusing on social capital and social networks, the importance of human experience and capabilities pales. Recent literature, by adding human aspect to sustainability, tries to emphasize the importance of investment in human capital in order to encourage the cultivation of sustainable citizens through communication, education and well-being improvement. Sustainable citizens have high levels of awareness and knowledge towards sustainability while behaving in accord with sustainable principles. This view can help architects to create sustainable values for green consumers and also foster sustainable users. The most important factor for

having a sustainable planet is the cooperation of its population. Therefore, the awareness and behavior of people is crucial and related to social aspects of sustainability in terms of social fairness, justice and equity but completely different. One of the pivotal roles of interior designers is advocacy and education including engaging in advocacy work, community building and educating clients about sustainable behavior in interiors (Carlowitz, H. C. von., cited in 1713).

Table 1: Sustainability criteria for interior architecture

Sustainability Criteria		Explanation	References
Environmental Aspect	Embodied Energy	The minimization of total energy consumed for production of materials and products from extraction of raw material to construction site delivery.	Zeng & Chini (2017; Dixit (2017); Dixit (2019).
	Carbon Footprint	The minimization of greenhouse emission by choosing appropriate materials with green production process and choosing green methods of construction.	Sinha et al. (2016). Linag & Lee (2018); Sizirici et al. (2021);
	Outdoor Environmental Health	The minimization of Light pollution of the building for external environment; air and noise pollution during construction and during the residence of inhabitants.	Kwon et al. (2016) Jinfeng et al. (2021, June) Tomasovits et al. (2021, November)Wieser (2021)
	Renewable and Local Materials	Replacing non-renewable materials with renewable ones. Using local materials reduces the environmental degradation drastically.	Morel et al. (2001). Li (2016) Al-Baldawi (2015) Liang & Zhen (2015).

	Renewable Energy, Energy and Resource Efficiency	Utilization of energy sources such as sun, wind and water instead of fossil fuels. Energy and resource efficient solutions decrease environmental degradation.	Chel & Kaushik (2018) Shi & Chew (2022).
	Product Circularity	Utilization of products with complete and healthy cycling pathways.	Hagejärd et al. (2020) Joustra et al. (2022)
Social Aspect	Social Fairness	Utilization of materials and products which the suppliers are committed to human rights and fair working practices. The social impact of procurement should be considered.	Ünal & Shao (2019) Ayidi & Yehya (2022)
Economic Aspect	Supporting Local Businesses	By employing local workers and purchasing from local businesses, the interior design project can support the economy of that region.	Walker & Preuss (2008).
	Cost	The budget-friendly solutions can encourage clients to go green. In addition, energy saving solutions are also cost-cutting solutions for clients.	De Jonge (2005) Melaver & Mueller (2009) Kurnitski (2013) Hayles (2015).
	Payback Period	Attractive payback periods for sustainable solutions can persuade clients to pay the additional costs of sustainable solutions.	Coimbra & Almeida (2013); Jafari et al. (2014) Imteaz & Ahsan (2018)
Human Aspect	Indoor Environmental Health	improving indoor air quality, decreasing sound pollution. Light design.	
	Fostering Environmental Awareness	Interior designers can foster environmental awareness by their designs, demands and even their presence in social media. Educating future interior designers also can help to foster environmental awareness.	Garcia (2012). Sameh (2014) Tabuenca et al. (2020) Aramburu (2021).

	Design for Sustainable Behavior	Interior designers should consider for design opportunities which would cultivate sustainable behavior in inhabitants.	Hakky (2016) Al-Ashraf Shrief (2021) Scurati et al. (2021).

Interior designers in today's world have a significant impact on sustainability of our planet. In accord with the vision of world urbanization prospects developed by The United Nations Department of Economic and Social Affairs (UNDESA) and sustainability organizations such as LEED, interior designers should be an active agent in constant interactions with all stakeholders in order to create sustainable interiors in sustainable buildings for creation of sustainable cities and communities. Interior designers in present era can be inspired by different periods of history of interior design to create styles and contexts for their designs, while considering modern global issues related to sustainability. The goals and criteria of sustainable interior designs are clear and interior designers are responsible to advocate these aims and criteria in order to have more sustainable stakeholders including investors, policy makers, clients and engineers involved in creation and usage of interiors.

Chapter 3

SUSTAINABLE RESIDENTIAL KITCHEN

In this chapter, the sustainable residential kitchen has been described from two aspects. First, the general considerations in sustainable residential kitchens have been elaborated. Second, the components of sustainable residential kitchen have been introduced and their respective guidelines have been provided.

3.1 General Considerations in Design of Sustainable Kitchens

Environmentally sustainable kitchens as crucial part of sustainable houses are budget friendly in long run due to being energy efficient (using efficient systems and appliances), having lower initial budget (using second hand options and/or local and abundant materials) and being functionality-oriented involving considerations regarding durability and human health. But their importance goes even further. They reduce carbon footprint and contribute to a healthy planet (Ashfaq, 2023; Patil, Boraste & Minde, 2022). In literature, it is stated that the following considerations must be taken into account by designers to create sustainable kitchens:

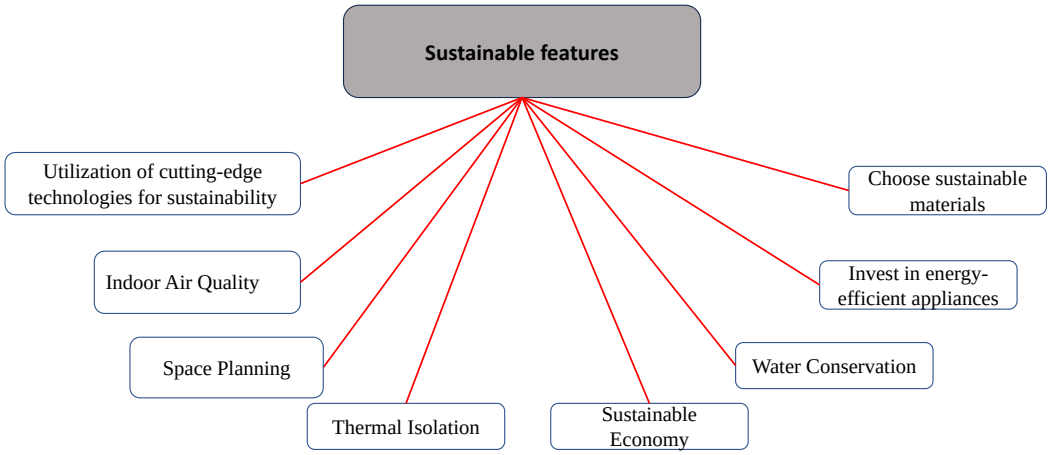

Figure 20:Sustainable residential kitchen in today's world

3.1.1 Space Planning

A sustainable kitchen should be designed considering ergonomic, functional and safety factors. To make a residential kitchen more functional through space planning, following these guides are suggested:

The kitchen space should be designed in a way that two cooks would be able to work without running into each other. Designing the main walkway so that it's not a hazard when opening appliances is a safety recommendation (Ollár., Granath, Femenias, & Rahe , 2022).

There are common layouts used in the kitchens, L-shaped, U-shaped, G-shaped, single-wall, and galley kitchens (Atamewan & E-Out, 2018). In all these layouts it is important that the main items, sink, refrigerator, and stove be within quick reach of each other to avoid complicating tasks. A minimum distance of 117 Centimeters ensures that cabinet doors can open from both sides (Mira Ahn,Kathleen R. Parrott,Julia O. Beamish &JoAnn M. Emmel, 2008). Figure 10 illustrates the concept of the kitchen working triangle (Akçaova,2024,page 185). The working triangle refers

to the interconnection between storage (refrigerator), washing, preparation, and cooking. It reduces the amount of time that kitchen users will spend in the kitchen and enables them to engage in the meal preparation process without experiencing excessive fatigue. The total length of the three sides of the optimal working triangle should range from 12 to 23 steps, equivalent to 360 to 660 cm. There should be no additional pathway or object (table, chair, etc.) that intersects with the work triangle.

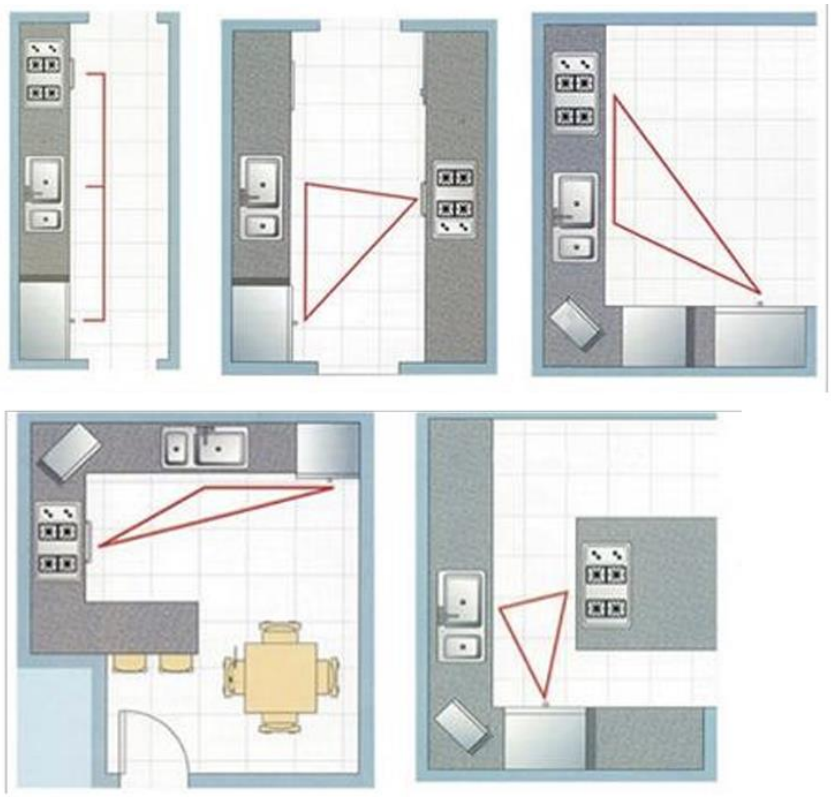

Figure 21: Kitchen working triangle model, (Akçaova, 2024, page 185)

If an island is used be careful that it doesn't block the area in front of main appliances and that it’s far away enough for comfortable access (Hanci, Burçin (2012).

Choosing storage items that are functional and easy to use such as pull-out trays is recommended (Maller, Horne & Dalton, 2012). In addition, adhering to local building codes, trusting licensed professionals for electrical and plumbing tasks, and

prioritizing safety to create a kitchen that is both functional and safe are suggested (She et al., 2023).

3.1.2 Choice of Materials

In choosing materials used in the construction of a kitchen there are several general criteria to be considered and general terms to be discussed. These are as follow:

Embodied Energy

The amount of primary or non-renewable energy consumed during a building material's life cycle is referred to as "embodied energy." It includes extraction, processing, manufacturing, transportation and installation. When assessing the sustainability of materials and products used in buildings, this is really important. By considering embodied energy, decisions can be made that reduce the amount of energy needed to produce materials, which makes the building more eco-friendly. The designer can be presented with the biggest challenge when it comes to selecting materials because every product is a component of a larger whole (Reddy & Jagadish, 2003).

Materials have different levels of embodied energy. So, by choosing materials with lower levels of embodied energy, the overall energy efficiency of a building can be enhanced. As an example: natural stone, solid wood and soil all usually have lower levels of embodied energy than non-renewable or highly processed materials. This is why designers must have both awareness and consideration for this when pursuing sustainable construction approaches (Azari & Abbasabadi, 2018; Cabeza et al., 2013a).

To comprehend what embodied energy means, we need some guidelines and vocabulary provided by DuPont's "Glossary of Common Sustainability Terms":

- **Cradle-to-gate:** This tests a product's life cycle from manufacturing to the factory gate. This is usually the point at which it is sent to a warehouse, installer, or consumer.
- **Cradle-to-site:** A life cycle assessment of a product from when it leaves the manufacturer to when it arrives at your home.
- **Cradle-to-grave:** This test checks everything from a product's time in your house (including repairs) to the end of its useful life and where it will end up after you've thrown it out.
- **Cradle-to-cradle:** A design philosophy that aims to reduce waste by reusing materials or products at the end of their useful lives to create new ones rather than burying them in a landfill. For an embodied energy calculation, this starts with raw material extraction (including any fuel needed for that process), raw material transportation to the manufacturing plant, energy used at the plant, and packaging used to ship finished goods (Davis & Fisher, 2015).

Life Cycle Assessment

Taking into account the complete lifespan of a product, the life cycle method provides a more holistic perspective on material selection. Life Cycle Assessment (LCA) is a comprehensive assessment of the environmental impact of a product, beginning with raw material acquisition and ending with disposal. Here are few things that it encompasses: Building decommissioning and demolition; Material disposal, reuse, and recycling; Resource extraction and product/materials transportation; Material processing and product manufacturing; On-site building construction requirements; Occupancy and maintenance considerations; (Bribián et al., 2011; Petrovic et al., 2019).

Lifecycle assessment (LCA) is an effective tool for measuring the environmental influence of appliances, fixtures, and materials (Bruce-Hyrkäs et al., 2018; Tsai et al., 2014). There are three major steps to think about when using LCA to assess products:

1. **Goals have to be determined:** The sustainability objectives should be determined carefully. Some factors to consider include low maintenance, high recycled content, water conservation, high energy efficiency, indoor air quality (IAC), and local product sourcing.
2. **Life cycle inventory:** This step evaluates the energy consumption throughout manufacturing, as well as the energy input at each stage of production. The objective is to comprehend the constituent elements used in the production of a product.
3. **Impact assessment:** This section examines the waste generated during manufacturing and its potential to cause harm to both individuals and the environment. This stage assesses our progress in mitigating acid rain resulting from climate change or depletion of fossil fuels. Next, is the examination of the impact of indoor air contamination (IAC) on the product as well as the quantity of volatile organic compounds (VOCs) it emits. This analysis will consider the expenses associated with installation and the necessary supplies for regular maintenance. Finally, it should be evaluated based on its effectiveness once it becomes obsolete. Is it capable of being reused or recycled? Is any garbage disposed of? (Zou et al., 2017; Collinge et al., 2015; Al-Ghamdi & Bilec, 2017). However, sustainability is not the sole component of the problem. When considering the broader perspective, it is important to take into account factors such as maintenance, aesthetics, physical limits, and longevity (Davis & Fisher, 2015).

Choose materials that are not only environmentally friendly but also add some unique touch to the kitchen design. Using reclaimed materials like salvaged wood or furniture can reduce waste and promote sustainability. Also, it is beneficial to prioritize materials with low volatile organic compounds (VOC) emissions like bamboo or cork to minimize harmful chemicals in the environment. Plastics take hundreds of years before they decompose and they pollute our waters. Thus, it is advised to avoid using plastics in the kitchen design to reduce pollution. Some examples of sustainable materials that can be used in design of kitchens are as follows:

- Wood: And not just any wood, it is advised to use natural wood materials that are FSC (Forest Stewardship Council)-certified for sustainability
- Bamboo: One of the most common green materials used in building, known for its sustainability and durability
- Consider utilizing cork for flooring or other components in the kitchen because of its renewable characteristics.
- Recycled Glass: it is suggested to use recycled glass for countertops or other surfaces to reduce environmental impact
- Stainless Steel: Choosing stainless steel for appliances and fixtures are recommended as it is durable and recyclable
- Salvaged Wood: Incorporating salvaged wood into the kitchen design to add a unique and sustainable touch is a viable option. (Singh, Colangelo & Farina, 2024; Nayar, 2009; Han, 2012).

3.1.3 Sustainable Economy

Supporting local economy and partnering with artisans and manufacturers who live locally and have similar sustainable values is advised. Economic initiatives can be created through these types of collaborations which can be highly assistive to

sustainable development within a region. (Koengkan et al., 2023; Phillips, Seifer & Antczak, 2013). Using local sources and materials not only can support local businesses but also reduces transportation-related carbon emissions.

Considering second-hand options as budget friendly sustainable solution and looking through the local thrift stores or online marketplaces are always budget friendly options (Luchs et al., 2011); Lane, Horne & Bicknell, 2009).

3.1.4 Water Conservation

Interior designers can save water in residential kitchens through various methods:

- Choosing Water-Efficient Fixtures and Appliances: Choosing faucets, dishwashers and washing machines with the WaterSense or Energy Star label which ensure water efficiency and performance is recommended (Tam & Brohier, 2021).
- Implementing Rainwater Harvesting Systems: Installing a rainwater harvesting system to collect and reuse rainwater for purposes like washing dishes is suggested (de Sá Silva et al., 2022).
- Utilizing Greywater Recycling Systems: Incorporating a graywater recycling system that reuses wastewater from sinks, showers, and washing machines for non-potable purposes such as flushing toilets or irrigating gardens is advised (Pradhan et., 2019).
- Flowing Low: Choosing fixtures that are low-flow, which can reduce the flow rate by up to 50% without compromising pressure or quality is recommended (Sheth, 2017).
- Education is Key: People might not even know where to start when it comes to saving our most precious resource. Therefore, it is wise to let them know how

they can be more water-efficient with their fixtures and appliances (Mailloux, 2011).

3.1.5 Energy-Efficiency

Energy efficient appliances contribute to sustainability through hindering environmental degradation and facilitating economic initiatives. ENERGY STAR labeled appliances which meet strict energy efficiency guidelines can provide energy efficiency in the kitchen (Ganda & Ngwakwe, 2014).

To achieve sustainability in a residential kitchen through lighting considerations, incorporating natural lighting is key. Utilizing natural light sources like skylights, windows, solar tubes, or glass doors leads to reducing energy consumption by minimizing the need for artificial lighting. Additionally, considering energy-efficient LED bulbs that use at least 75% less energy and last up to 25 times longer than traditional incandescent bulbs is advised. By choosing sustainable lighting options and maximizing natural light, designers can create an eco-friendlier and energy-efficient kitchen design (Lechner, 2014; Whitehead, 2008).

3.1.6 Thermal Isolation

The insulation of walls or floors next to the kitchen retains heat in the interior during winter, so reducing energy consumption and lowering utility costs. This can also aid in reducing noise. The efficacy of insulation is assessed by its R-value, which quantifies its capacity to impede heat transmission. For determining the appropriate kind and thickness of insulation, it is advisable to consult the minimum suggested R-values specific to your region (Adamczyk & Dylewski, 2017). Regarding kitchens, which often experience less significant temperature fluctuations compared to other areas of the home, the appropriate insulation R-value may differ.

Adding insulation to the kitchen is an effective method for reducing energy costs and preventing unpleasant drafts from infiltrating via walls or floors that are linked to external areas. Greater R-values offer superior insulation compared to lesser values. If the building is located in a cold region, it may be necessary to utilize thicker insulation or select insulation with superior performance to provide the best possible outcomes (Tuohy, McElroy & Johnstone, 2005).

3.1.7 Indoor Air Quality

Interior designers may reduce the presence of pollutants in sustainable home kitchen designs by employing a range of environmentally friendly strategies. Several methods to do this consist of:

Utilizing low-VOC paints: Conventional paints consist of volatile organic compounds (VOCs), which have the potential to be detrimental to both the environment and human health. Use paints with low volatile organic compound (VOC) content or paints that do not contain any VOCs (Auvinen & Wirtanen, 2008).

Utilizing low-emission materials: It is recommended to choose materials like natural latex foam, organic wool, solid wood furniture (such as walnut and teak), and natural fibers for carpets (wool, cotton, jute) in order to minimize the release of volatile organic compounds (VOCs) (Yu & Kim, 2012).

Improving Ventilation: Implementing effective ventilation systems to decrease levels of indoor pollutants and enhance the quality of air (Hesaraki, Myhren & Holmberg, 2015).

Implementing Biophilic Design: Utilizing biophilic design features such as indoor vegetation, vertical gardens, and organic materials such as stone and wood to improve visual appeal and indoor air quality (Zhong, Schröder, and Bekkering, 2022).

3.1.8 Utilization of Cutting-Edge Technologies for Sustainability

Interior architects can use new technologies in the process of design and construction to enhance sustainability in the kitchen. The followings are some of technologies that can be used for this purpose:

- **BIM** modeling of the kitchen for space planning and sustainability-related measures and estimates: BIM (Building information modeling) is a powerful tool for creating sustainable kitchens by integrating sustainability criteria in the early stages of the design process, optimizing building efficiency, and promoting passive design strategies. By creating a shared digital database for building information, BIM facilitates collaboration among various stakeholders in the construction industry, ensuring that the client's needs and demands are met while promoting sustainable building practices (Jalaei & Jrade, 2014; Tushar et al., 2021).
- **AI (Artificial intelligence)** for automating the control for more easy and affordable sustainable behavior in inhabitants: AI can be used to develop real-time warning systems to prevent excessive energy use and promote eco-friendly behaviors in buildings. (Shikhli et al., 2022 b; Saba et al., 2021).
- **Nanomaterials**: They are an important part of creating sustainable homes. They help with material efficiency, energy efficiency, and environmental quality. Nanotechnology is improving the way we use energy in our homes. For example, they can be used to create better insulation. This means spending less energy heating or cooling in the house. Additionally, windows and glazing

can be improved using nanotechnology as well which will reduce thermal loads. It also helps improve material efficiency by reducing the amount of raw materials needed while still maintaining structural integrity. Lastly, it improves the environmental quality of buildings by reducing pollutants and toxins released into the air. A good example is coating materials that self-clean so you don’t have to use harsh chemicals to clean them yourself. Another example is sensors that detect damage early so repairs don’t become costly and environmentally harmful later on (Gammampila et al.,2010; Shah & Xiong, 2020).

Chapter 4

GUIDELINES FOR SUSTAINABLE RESIDENTIAL KITCHEN

This section provides guidelines for designing sustainable kitchens according to extracted elements introduced in the previous section.

The considerations in design of a sustainable residential kitchen are illustrated in Figure 22 below. The identification of these factors has been accomplished by doing a thorough literature survey. The research sought to provide optimal methods and cutting-edge solutions for designing kitchen areas that are both ecologically conscious and sustainable. In the proposed guideline for the design of sustainable residential kitchens the criteria are gathered under three main headings: the factors related to design and construction of the main elements that form the space (walls, floors, etc.), the ones related to the furniture and fixtures used within the space (kitchen) and the criteria related to environmental conditions in the kitchen.

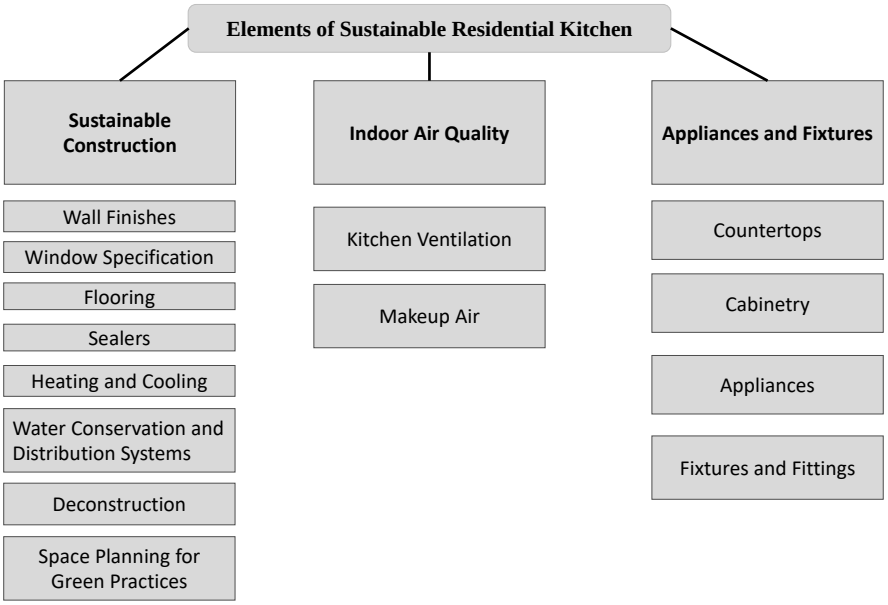

Figure 22 Figure 22: elements of sustainable kitchen

4.1 Sustainable Construction

Green building materials were developed with the aim of reducing the adverse effects of construction on the environment and promoting sustainability. Additionally, these materials have many advantages such as lower carbon footprints, better occupant health, energy savings, and fewer maintenance expenses. Generally composed of recycled materials, wood or adobe they are engineered to have as low of an environmental impact as possible throughout their lifecycle. Energy efficiency can be increased, indoor air quality can be improved, and harmful greenhouse gases can be reduced by using them. This includes products like wood bio-composites or even recycled steel in construction projects (Al-Atesh et al., 2023; Farzoni, 2011; Spiegel & Meadows, 2010).

Green cement, sometimes referred to as sustainable or green concrete, provides builders with a more environmentally responsible choice. The material is produced with residual or discarded resources from many sectors, including slag, fly ash, and

recycled aggregates - all secondary products of other industries. Green cement has ability to release up to 80 percent less carbon dioxide compared to conventional cement when it is being produced, and it also demands less energy for manufacturing. Reducing the carbon footprint of buildings and infrastructure is a major advantage of green cement. Geopolymer concrete, a type of environmentally friendly cement, is both stronger and more eco-friendly than Portland cement. It has a carbon footprint of around 10 percent, as stated by Bediako et al. (2016) and Phair (2006). The manufacture of green cement is ecologically advantageous since it utilizes resources that would otherwise be discarded. For instance, slag is a residual substance generated during the production of iron and steel, whereas fly ash is the leftover material from power plants that burn coal. Utilizing these materials in cement production leads to waste reduction and decreases the demand for new resources (Imbabi et al., 2012; Sivakrishna et al., 2020). Green cement offers environmental advantages, while also being cost-effective and aiding in the certification of structures as LEED green buildings. Experts forecast an increased utilization of green cement in the construction sector as the global community progresses towards a more sustainable future (Castro-Lacouture et al., 2009).

Recycled aggregates and supplemental cementitious materials (SCMs) are two examples of environmentally friendly ingredients used in sustainable concrete that lessen the material's negative environmental effects. Geopolymer concrete, which is another form of green concrete, involves repurposing fly ash, pulverized granulated blast-furnace slag, and other naturally occurring elements. Using sustainable concrete over Portland cement makes sense financially and environmentally because its carbon footprint is much smaller. While also not sacrificing strength, durability or energy efficiency which makes sustainable concrete an ideal fit for green building projects.

With the incorporation of sustainable materials and manufacturing methods, the construction industry has great potential to reduce its environmental impact greatly and encourage a more sustainable future (Ogunkah & Yang, 2012; 2013; Sandanayake et al., 2020).

Epoxy grout can work for green buildings too — as long as it's eco-friendly epoxy grout. For design purposes regarding high performance and longevity, non-toxic and non-hazardous to the environment are fantastic qualities found in eco-friendly epoxy grout plus they contain no volatile organic compounds. Similar to this approach, there are resin coatings that are safe for residential use, formaldehyde-free and good for the environment. These products show commitment to offering non-toxic and environmentally appropriate grout solutions for green building projects (Su et al., 2021; Wang et al., 2021).

Wall Finishes

Designers must carefully choose the appropriate finish for interior spaces in order to adhere to budget constraints, considering the extensive range of choices at their disposal. Green wall coverings, a burgeoning trend in interior design, are available in several forms, each with unique characteristics and advantages. Common variants encompass artificial plant walls, preserved moss walls, and real plant walls. Additional options for interior wall treatments include succulent walls, bio walls, vertical gardens, and green facades. Vertical gardens, suitable for both indoor and outdoor usage, are constructed using pre-cultivated plants and need minimal upkeep. Preserved moss walls, are a superb option for establishing a serene indoor ambiance. Artificial plant walls are low-maintenance alternatives that may be used in both indoor and outdoor spaces. In addition, succulent walls, bio walls, vertical gardens, and green facades have

distinct aesthetic and environmental advantages, making them adaptable options in interior design. The selection of green wall treatment is contingent upon the particular room and the intended aesthetic appeal, guaranteeing the most suitable match for the current interior design project (Gunawardena & Steemers, 2019; Meral et al., 2018; Peters, 2013).

Paint is the cheapest and most effective way to change a room. A fresh, consistent coat can make an entirely space come together, and color has an incredibly uplifting effect. Even still, many designers and contractors think that oil-based paints are stronger than latex or water-based paints today. However, solvents from oil-based paint will keep off-gassing for a much longer time than from water-based paint (Kaur et al., 2023; Knowles, 2013).

Traditional paints use high-VOC solvents derived from petrochemicals that off-gas. So, when specifying paint, looking for low- and zero-VOC formulas as opposed to traditional paints are recommended. These have the fewest hazardous emissions and provide good coverage. “Zero-VOC” is untrue — all paints contain volatile organic compounds (VOCs) — but no product labeled “zero VOC” has exceeded the relevant government thresholds. It’s worth noting that some zero-VOC paints emit fewer emissions than others of the same type. Paints are rife with this kind of greenwashing; relying on third-party testing rather than manufacturer claims when determining which brand to specify is advised (Binggeli, 2008; Schwartz, 2016).

“Natural paints” are available in water-, oil-, or milk bases and made from renewable or naturally occurring ingredients: citrus oil, lime, chalk, linseed oil, clay, casein. They don’t contain petroleum products and they don’t release as many volatile organic

compounds (VOCs) but they may still release VOCs due to additives such as citrus-based solvents. Some of the chemicals in natural products like citrus oil may be hard for chemically sensitive clients to tolerate, but overall these products are safer and healthier than regular paints in terms of their impact on the environment. Not all natural ingredients are safe: yellow pigment cadmium is toxic, so not everything is suitable to be used; paying attention to Material Safety Data Sheet (MSDS) ingredient lists for information on suitability are crucial (Weismann, & Bryce, 2008).

The least toxic and most environmentally friendly paints are milk-based, which are made from powdered casein. They should not be used in wet areas, like bathrooms or kitchens, because moisture will damage the finish and promote mold growth. It needs to be sealed if it's going to be used in these locations. A water-based, low-VOC sealer will help improve its benefits to the environment and human health. Milk-based paint needs preservatives added to it to extend its shelf life as well. If recoating is needed, a fresh batch is required because it only has a short life after being opened and the new layer may not match the original finish (Radding, 2017; Weismann, & Bryce, 2008). Natural paints take two or more days to dry and cost 20-80% more than conventional paints. They require a lot of prep work because they work best with clean, primed surfaces and do not typically stick well with latex or oil-painted ones that already exist (Edwards & Lawless, 2003).

Hand-applied clay-based compositions can make for custom, unique surfaces. Paying for customization price is required just for installation alone as it is time-consuming since it goes on in layers. Overall, the material costs about as much as premium paint but less is wasted since it is applied on-site in powder form and mixed with water. Minor wall damage can typically be fixed by homeowners themselves with clay-based

plaster but major issues might need professional intervention (Forsyth & White, 2012; Schwartz, 2016).

Clay-based tile gives many kitchen and bathroom interiors surface durability. Stone is another option that's stronger than ceramic tile but is also more expensive. In fact, stone might also be one of the most expensive materials used in a project period. The application requires a level dry surface too since substrates being uneven cause most problems when installing tile. Clay tile should also have thinset underlayment (a cement product) beneath it. As previously mentioned, cement has a high level of embodied energy. Tile installation should also have the grout sealed. The sealant will prevent stains whether the tile is a softer stone like marble or low-fire ceramic. As far as locally produced materials such as tile could give a project an artistic touch and tie it to the artisan culture in the area (Forsyth & White, 2012; Knowles, 2013; Schwartz, 2016).

Window Specification

The most important thing to know about a project is where its location geographically is. There are many different things to consider when building kitchen windows based on climate to ensure both comfort and efficiency. For cold winter and hot summer areas, selecting glass with a low U-factor and a low emissivity (low-E) coating leads to reflect the sun and give climate control in all seasons and temperatures. In often cold locations, choosing glass with a high solar heat gain coefficient (SHGC) and a low U-factor yields to keep as much heat in as possible while staying cozy inside. Adding a third glass pane can greatly decrease the energy costs of an insulated glass unit (IGU) (Lee 2010).

For cold winter and hot summer climates, experts recommend vinyl-clad wood or composite frames because of their insulating qualities and longevity. Fiberglass frames are recommended for frequently cold locations because of their durability and superior thermal performance. In mixed climates, spectrally selective low-E glass or Low-E coatings should be used to avoid keeping heat inside during summer or letting it escape during winter (Ariosto et al., 2019; He et al., 2019; Ware, 2011).

Where the windows go is also important. In high temperate areas, save small windows for the East and West while saving large ones for North facing homes where insulation will be improved (Kim et al., 2016).

The focus of sustainable buildings is on performance efficiency. While earlier green construction methods focused primarily on energy production and resource conservation, using construction techniques that allow your energy to stay inside your home while keeping external weather out is way more effective at reducing energy usage in homes (Ahn et al., 2016; Lee, 2010).

Flooring

For more than a century, cork has been installed as flooring. It is sound-absorbing, naturally soft and insulating (warm to the touch). Cork oak trees, which can live well over 200 years, can be harvested about every 10 to 12 years. Since cork is self-healing, most dents will disappear over time. After removing damaged sections, the flooring can be resealed. Cork resists water naturally so any number of cork flooring options can be used in kitchens (and other rooms). There are many choices and price points for cork flooring (Gil, 2015; Kim, 2009).

Frederick Walton developed linoleum in the late 1800s. The combination of natural pigments with a jute backing, linseed oil, pine rosin, wood flour, limestone and cork dust, among other renewable resources. Linoleum typically lasts for between 30 and 40 years in high-use areas because of its natural antistatic and nonallergenic properties. It's also good for the environment as it is made from the ground up using only natural elements and no environmental pollutants are used during any stage of production or disposal (Einstein, 2008; Ferenc, 2010; Kim, 2009).

Since linoleum is made with linseed oil, when it is first installed the flooring will amber (or yellow). Liquid linseed oil is yellow. When exposed to light the solvents will evaporate and take the yellowing with it. Cleaning will not speed this up; only time and exposure to natural light will return it to its original color. Linoleum doesn't need regular waxing; maintenance consists of sweeping and routine mopping — which means very little besides some elbow grease. Cuts, scrapes and burns can all be healed by professionals easily (Dixit et al., 2019; Kim, 2009).

Sealers

Several factors determine whether a sealer is used on a finished surface: the type of material (concrete, granite, marble, soapstone, limestone, wood, etc.); where it's installed (showers, countertops, walls, floors); whether or not the client will reapply; and what the sealer will do to indoor air quality. Why does a product need to be sealed? The sealer's job is to protect a surface from etching and staining. Not every sealer is equal or appropriate for every surface (Binggeli, 2008; Shen et al., 2016).

There are two types of sealers that are commonly used for stone, concrete and tile — topical and penetrating (or impregnators):

Penetrating sealers get into porous materials (the material then absorbs less liquid less deeply and discolors less). The final look remains the same. Bare concrete must be treated with a penetrating sealer before staining it. For polished or honed concrete surfaces — including countertops and sinks — this kind of sealer is best. When using tile with crackle glaze in a shower it should be treated with a penetrating sealer that inhibits mold and mildew growth. Soapstone can be sealed with mineral oil (Adil et al., 2021; Litvan, 1996; Xiao et al., 2020; Mamaghani et al., 2009).

Topical sealers include epoxies, acrylics and wax. Wax is the simplest basic sealer that is poured onto bare concrete (carnauba + beeswax; not penetrating). It gives the concrete a low-to-high-gloss finish that either enhances or darkens its sheen; it's very forgiving and easy to apply; anything left behind dries into the finish — but wax won't scratch; warm weather can melt this finish; acidic substances like vinegar or lemon juice will dissolve the wax and create an etch in the underlying surface if they aren't wiped away right after they've contacted the floor; acid stains will etch waxed concrete faster than plain water will do so. Solvent-based or acrylic sealers are most frequently used on concrete (easily scratched but harden after drying and offer good stain resistance; the concrete's exposed surface is then vulnerable to stains). These have a lot of volatile organic compounds. Epoxy sealers are very "green" but aren't very stain resistant. Concrete epoxy sealer is expensive and should be installed by a specialist (Binggeli, 2008; He et al., 2020; Kishore, 2015).

Heating and Cooling

The energy used to condition interior spaces is the largest consumer in a building. An HVAC (Heating, Ventilation, and Air Conditioning) system accounts for more than a third of all the energy used by commercial buildings in the United States. In winter it's

heat; in summer it's cooling. HVAC systems in green buildings use less energy than those in conventional structures, make interior conditions more comfortable and reduce pollution and carbon emissions (Khabiri & Ghavami, 2015).

A test of both heating system and air conditioning is part of a Home Energy Rating System (HERS) rating — an increasingly popular method of measuring the energy efficiency of residential structures, including green buildings. Home Energy Rating System (HERS) measures hot water, heating and cooling systems to produce an index score that reflects how well or poorly a house performs in terms of energy consumption: The higher the score, the worse it performs; 100 would be average for new homes built to current code; below 100 is better down to zero, which represents zero-net-energy performance. Retrofits can earn negative ratings if they perform better than a new house built to code minimums (Krarti, 2008; Reeder, 2010; Zhang, 2021; Zhao et al., 2016).

According to the Residential Energy Services Network (RESNET) website, a home with a HERS index of 70 is 30 percent more energy efficient than a typical new home. On the other hand, a typical new home is 30 percent less efficient than an old house that has a rating of 130. A newly constructed house consumes between 15 and 25 percent of its total energy in duct leakage, says the LEED for Homes Reference Guide. In an insulated core inside the house, there are no problems with leaky ducts. If they are housed in crawl spaces or any other uninsulated location, then it is a problem (Davis & Fisher, 2015).

If applicable, implementing a radiant heating system in the kitchen is recommended. A radiant heating system transfers heat directly through the walls, floors, or ceiling of

a room. The warm air rises through a process called convection, delivering heat to the entire room. Radiant heating systems are a popular choice among green buildings because of its energy efficiency and thermal comfort. They use radiant heat transfer to directly transport heat to the floor or panels installed in ceilings and walls, using infrared radiation for warmth. Some people express concerns that extremely insulated homes may not be suitable for radiant floor heating despite their high energy efficiency and comfortability. However, this is false. It's actually a great option for high heating load homes and those located in colder climates. A mat of conductive filaments under the finished floor could be used to create a radiant-heated surface beneath the finished floor. Ceramic tile is one of the most effective conductive flooring materials you can get your hands on. Don't forget to do some research on how different types of flooring handle warranty issues with radiant heat systems (Fink, 2010; Glick & Guggemos, 2010).

Zonal heating/cooling is an interior layout design that involves user-controlled zones to provide personalized thermal comfort while reducing the amount of energy used within a green building. In simple terms, it's about breaking down your structure into separate areas and managing each independently. To achieve this strategy, an HVAC zoning system would need to regulate each section individually based on factors such as occupancy and temperature. Individual zone thermostats should be placed in convenient places like next to light switches in order to make things easy for users. Whole house systems may be useful when designing structures with this type of zonal control detail. Multi-split VRV (Variable Refrigerant Volume) type ductless systems and variable refrigerant flow (VRF) systems are two methods commonly used within zoned heating and cooling green buildings but they require professional help (Beizaee et al., 2015; Scott et al., 2022; Wright, 2021).

Heat pumps are appliances used instead of traditional air conditioners and forced air furnaces known for their ability in providing both hot and cold air inside buildings. These renewable energy using appliances are highly favored due to their environmental benefits within green buildings. The two main types of heat pumps include ground-source (or geothermal) and air-source heat pumps, with the latter being more common. Heat pumps use mechanical energy to push around heat from cold areas to warm ones. Unlike forced-air systems, they don't produce additional heated air. Instead, they use the existing air in a space to be efficient. This makes them great for extensions that don't have an open path for ducting. With no need for a fuel source like traditional heating systems, heat pumps focus on using 100% clean energy when powered by renewables within buildings (Sang et al., 2022; Wang et al., 2021; Yunna & Ruhang, 2013).

Conventional ventilation methods are effective for ensuring good indoor air quality. It is possible to recover between 60 and 80 percent of the heat from warmed air using a heat recovery ventilator (HRV). During temperate months when cool outdoor air moves indoors, it warms up against used but warmer stale air, as shown here. In summer, it's reversed: hot outdoor air cools against cold indoor air (Jeon et al., 2023; Kim et al., 2012; Zender–Świercz, 2021).

In colder climates where temperatures are typically below freezing during winter months, builders commonly install HRVs to deliver steady streams of fresh filtered weather to home occupants without spending excessive energy on preheating it first. A heat exchanger recovers heat from exhaust air and transfers it to incoming fresh air during cold seasons. When used properly — meaning not in extremely humid or dry conditions — ERVs also can recover energy from a home's exhaust air to condition

incoming fresh air. But instead of heating or cooling the outdoor air, an ERV captures energy from its humidity. As explained here, it uses the thermal properties of bland indoor air to better condition fresh dry outdoor air during winter months. Warm wet indoor air is brought into contact with cool dry outdoor air, moving in the opposite direction, which picks up moisture and heat. “Dew points” is a term used to describe this process as well as relative humidity levels that are often described in weather forecasts. The exact reverse process — precooling and dehumidifying incoming air — is employed during summer months. It’s great for any type of building in all climate zones because it both improves indoor comfort and lowers energy consumption. In hot tropical regions, where buildings are cooled much more than heated, ERVs were historically recommended. They help by pre-drying incoming hot humid outside air before it contacts cold surfaces inside that could condense moisture on their surfaces (Al-Waked et al., 2021; Lam et al., 2005; Lemcoff & Dobbs, 2007).

Water Conservation and Distribution Systems

Water distribution and conservation in green buildings use a lot of techniques and technology. The main goal is to help conserve water in the areas that need it most by doing things such as using native, drought-tolerant landscape plants. This helps due to how scarce water is and how half of the world's population is estimated to live in a water-stressed area by 2025. They do this because they know that the best way to conserve water is to design a building with water efficiency in mind. This means being mindful with every drop of water used by putting low-flow fixtures in place, as well as collecting rainwater and recycling greywater — which are all ideas supported by the U.S. Green Building Council (Das et al., 2015).

One thing can be done during a remodel or new construction project would be to provide hot water on demand. An average tank water heater will store between 80 and 320 liters of hot water so it's always available for when someone needs it, but that also means that large amount of potential heated water will sit untouched for hours at a time when no one is around. That's a lot of wasted energy when an on-demand or tankless water heater will only heat up however much water you need right then and there, plus they're mounted onto the wall so they won't take up floor space either. Even if it costs substantially more than conventional tank heaters, customers will see a thirty percent reduction in their energy bill because they won't have to pay for unnecessary hot water from an unused tank anymore. In addition, several smaller units can be installed near where they're needed on bigger projects — like theaters or museums — so there's no need for users to wait an extra few second for cold water to run out before warm/hot even starts flowing (Brazeau & Edwards, 2013; Zhang & Zhang, 2012).

Insulating exposed hot-water pipes, especially those located in unconditioned spaces, is an easy way to reduce energy loss through plumbing. Looking at it from another angle, the use of graywater isn't actually very common among green building architects and contractors. However, a new movement to rough it in during new construction is slowly picking up traction even though most plumbing codes don't allow for it. Graywater is defined as wastewater that was previously used to wash clothes, dishes or take showers — and now it can be used to water gardens in certain areas. So, it's no surprise that some states like Arizona that are struggling with water shortages do have rules for those who want to use graywater in their yard irrigation. The California Green Building Standards Code (CAL Green) provides guidelines for graywater system design, modification and maintenance that include restrictions on

using spray irrigation and using diverter valves to control graywater (Buchanan , 2011; Waidyasekara & Rameezdeen, 2013).

Point-of-use (POU) water heaters are energy-conserving and water-saving appliances that are often found in green buildings. To lower the amount of energy that is required to pump hot water around a building — as well as reduce heat loss in distribution systems — these heaters are placed close to basins or showers. In addition, they can provide hot water instantly because they don't have a standing reserve like traditional storage units do. And because these devices can be powered by electricity or gas, they can lower energy consumption even further by eliminating standby losses commonly associated with heating large tanks of stored water. POU units also have potential benefits that include reducing pipe-water waste or allowing hot-water delivery without running a pipe all through an otherwise unconditioned space (Mantha et al., 2021; Rhoads et al., 2016).

Deconstruction

Activated in kitchen construction, deconstruction is the methodical dismantling of old kitchens and using materials to their fullest extent for ultimate resource efficiency. Through requiring less energy use, raw materials to be consumed and pollution of this precious resource, prolonging the lifespan outperforms recycling in a more ecological way. Deconstruction also offers the ability to recycle materials while taking down a house.

Deconstruction supports the 3R Strategy (Reduce, Reuse, Recycle). The advantages of deconstruction in kitchen are as follows:

a) Waste Diversion: Up to as much as three-quarters (75%) the outdated kitchen materials will be diverted from landfills. This lowers the negative impacts on environment in disposing of trash.

b) Saving resources: By saving and reusing kitchen appliances, the process also reduces reliance on expansion of new sources leads to better use of natural resources.

c) Employment Generation and Socio-Economic Impact: De facto, kitchen dismantling is not only about generating employment for people doing the job. Deconstruction (e.g. ripping out cabinets and selling salvaged countertops) opens up more jobs, promotes the local economy, and allows for resource thriftiness within our neighborhood.

d) Protection of Biodiversity: This is very important to consider in deconstruction process.

e) Reducing the ecological Footprint: In the deconstructing, preservation and saving the environment-keeping kitchen items with historical importance in circulation helps cut down on manufacturing new stuff, and is one way to save landfill space.

e) Energy Efficiency: Reusing the kitchen resources, reduces energy required to create and transport new materials for upgrading in a more economical way resulting in more efficient sustainable kitchen make over.

4.2 Indoor Air Quality

Indoor Air Pollutants

IAQ (indoor air quality) poses significant health risks — lung cancer, infections and long-term respiratory conditions like asthma are just some examples — but it can also

cause fatigue, headaches, dry eyes, nasal congestion and nausea (Gonzalez-Martin et al., 2021). Here a list of common indoor pollutants are provided:

Biological: In kitchen, biological contaminants like mold, bacteria and viruses can be seen in high humidity areas and the situation becomes worst when food is also left over. Such pollutants can be the cause of allergic reactions, diseases and various respiratory disorders. To avoid the spread of harmful organisms in cooking environments the ventilation systems should be working well for proper air flow, reduce moisture levels and keep surfaces sanitized. The relative humidity should be between 30% and 50%, since at levels below this threshold, mold spores will begin to form once germs. This can be done by means of dehumidifiers and enough ventilation. Additionally, regular cleanings should be conducted on all kitchen surfaces, but more attention needs to be paid to those that can cause food spills and are moist because they offer an amazing place for the pathogenic microorganism (Moldoveanu 2015; Binnie 2021).

Radon: It is a naturally occurring radioactive gas that can enter kitchens through foundation cracks and other openings. Radon is a well-recognized health hazard, causing lung cancer deaths and this radioactive gas can be found everywhere at home including the kitchen. Elevated radon levels can be dangerous especially in ill-vented locations. Using range hoods alone confirm to be minimally effective way towards reducing radon levels, adequate circulation flow within the kitchen is essential (Al Jassim & Isaifan, 2018; Ratnawati et al., 2018; Tsakas et al., 2011).

Asbestos: Asbestos a nonflammable silicate mineral, was used in several home articles the most frequent of which is kitchen articles. There are thus possibility of discovery of Asbestos in places such as old insulating Franchises, flooring Tiles and some

textured paints in the kitchen. Effects of asbestos fibers include illnesses to the respiratory system, especially lung cancer, mesothelioma and asbestosis which constitutes lung tissue fibrosis.(U.S. Environmental Protection Agency, URL 10).

It is recommended to check for presence of the asbestos in older kitchens due to hazard associated with it particularly when doing repair or improving the kitchen fixtures. According to EPA, a product containing asbestos is not dangerous as long it is left unperturbed with the product in good condition. Yet, the act of scraping these materials, that includes repairs, sanding or cutting for instance, might lead to fragmenting and liberating tiny asbestos fibers into the circulating air, thus posing a threat to one's health.Areas in the kitchen that may contain asbestos should be examined to find any signs of weakening, abrasion, or dampness. Whenever it is necessary to eliminate asbestos, it is important to let professionals dealing with this kind of works, who received the proper training and would be accredited. This is essential in preventing the circulation of the inflames asbestos fibers within the atmosphere. The major aim of the EPA's asbestos removal regulations is to minimize significant exposure of this toxic substance to the public (Flynn et al. , 2000; Lippmann, 1993; Sebastien et al. , 1982; Tomassetti et al. , 2020).

Kitchen Emissions from Combustion: Emission of combustion pollutants arises from kitchen equipment that use fuel for heating and cooking for example stoves, ovens, and heaters. The two most dangerous gases are nitrogen dioxide and carbon monoxide, which form together with other compounds the dense aerosol over the cities. They both are colourless and odourless gases. Carbon monoxide deletes oxygen in the body and causes headache, fatigue, nausea, confusion, and possibly death. It is widely known for causing throat irritation, inflammation of the throat, nose, and eyes,

and thus respiratory difficulties and infections. It is required to put the carbon monoxide detectors in the Kitchens. Use of clean fuel sources and energy efficient appliances including those used in cooking and heating lowers on indoor air pollution and provides good indoor air quality standards (Balmes, 2019; Gonzalez-Martin et al. , 2021; Luengas et al. , 2015; Zhang & Smith, 2003).

Formaldehyde: Formaldehyde is used in kitchen adhesives, bonding agents in kitchen particle board used in cabinets, plywood paneling, upholstery fabric, and carpets. Hazardous effects of formalin comprise dermatitis, cephalalgia, vertigo, hackles, and irritation of the ocular, nasal, or pharyngo-mucosa. To limit quantity of toxic materials in the kitchen, it is advised that accessories and construction materials with least or no content of formaldehyde be used. Examples of such materials are Stainless steel, solid wood and brick. When selecting new kitchen cabinet or countertop goods having low emission of formaldehyde should be preferred. Improve the air circulation in a kitchen, by opening the windows, turning on the fans or AC, can reduce the effects of Formaldehyde. Also, it is recommended to control the level of humidity and create comfortable temperatures with the help of air conditioning and dehumidifiers. This is important since, under conditions associated with high humidity and temperature, the rate of formaldehyde emission is higher (Lu et al. , 2021; Luengas et al. , 2015; Sekine & Nishimura, 2001; Shao et al. , 2020; Yue et al. , 2021).

Kitchen Ventilation

Ventilation moves air. Cubic Meter per Minute (m3/min) is a unit of measurement for air movement. What m3/min to specify will depend on what type of cooking equipment is used in the kitchen. Gas cooking surfaces may need more m3/min than

most electric cooktops. The number of bends in the ducting affects the fan motor size needed (Sun & Wallace, 2021).

A green building's appropriate kitchen ventilation system should prioritize energy efficiency and maintaining a high standard of indoor air quality. This can be accomplished by planning and putting in local exhaust systems in the kitchen, covering every burner with range hoods, and making sure the ducts are fitted and scaled correctly to vent to the outside. Furthermore, makeup air for kitchen exhaust should be taken into account, particularly in small buildings, to avoid depressurization and possible gas leaks into the structure. The U.S. Green Building Council additionally highlights the necessity of adhering to particular ventilation specifications, which include the layout and setup of local exhaust systems in the kitchen. In general, the ventilation system should balance energy efficiency with the upkeep of a healthy indoor environment—a prerequisite for a green building (Clark, 2012; Dhane & Jagtap, 2021; Liu et al., 2020; Willers et al., 2006; Zhou et al., 2016).

Makeup Air

Makeup air is an essential component of a building's ventilation system that brings in fresh outdoor air to replace air that has been exhausted from the building. It is designed to maintain proper air pressure and ventilation, ensuring a healthy and comfortable indoor environment. Due largely to modern construction technology producing more energy-efficient homes with tighter construction practices than ever before—meaning less air leakage into (or out of) housing—larger ventilation equipment creates greater negative pressure imbalances within houses. And while we know that ventilation is designed to remove pollutants and HOGS from dwellings, it also removes fresh air in

the process. This can lead to other problems, such as the introduction of radon and the backdrafting of combustible equipment (Jia & Yi, 2013).

Makeup air has been required by IRC (The Internal Revenue Code) energy codes since 2009. The designer and the HVAC contractor have to decide which system best suits client budgets and code requirements. But the designer is also tasked with educating clients enough so that they know how to properly use the system in their homes. Kitchen ventilation above 11.327 m3/min requires makeup air (Crowther & ENG, 2014).

When a mechanical ventilation system is installed, the pressure inside the house will change. Imbalances in building pressure are caused by two things: naturally occurring phenomena and mechanical system activities. Positive or negative pressurization is caused by pressure imbalances surrounding a structure that are caused by naturally occurring phenomena like wind and temperature variations. Conversely, mechanical systems—such as ventilation and air handling systems—are purposefully integrated into building designs in order to generate pressure variations by expelling or supplying air at uneven rates. To keep up with both of these components' effects, designers need a grasp on what they do together in order to maintain a balanced and effective building environment (van Straten & Brown, 2003; Lei et al., 2023).

For domestic use, makeup air systems come in different forms:

Powered or Fan-Forced Systems: These systems start up when the compensated exhaust system turns on, which happens when there's demand for makeup air in home kitchens.

Through-the-Wall Systems: To balance how much air enters and leaves spaces, these systems can be mounted at ceiling level around kitchen perimeters. Airtight homes with minimal air leakage rely on these systems.

Conventional Ventilation Fans: By drawing in fresh cold air from outside structures, these fans replenish air that can't be recirculated. In order to maintain interior air quality, they're designed to heat and chill tempered fresh air that's supplied throughout buildings. There needs to be versatility when it comes to where residential makeup air systems can be installed in houses. They also have to be automated so they can adjust to changing exhaust air flow rates efficiently. (Brown, 1990; Crowther & ENG, 2014; Gutiérrez-Montes et al., 2010).

4.3 Appliances and Fixtures

To a great extent the choice of appliances and fixtures in a well-designed kitchen can be crucial and aesthetic as well as functional. This category includes components such as countertops, cabinets and appliances. In general materials used for these items should be hard wearing, easy to wash, and should not be easily stained, or be affected by dampness. A selection of materials common for countertop preparations are granite, quartz, and hardwood. Appliances relate to the amenities in the kitchen which include stoves, ovens, fridges, and dish-washers and among others. Such appliances have to be as energy saving as possible, blend with the rest of the kitchen, and meet cooking and storage needs of the household. Fittings & Accessories should improve the design and be practical; these include; sinks, faucets, and lightings among others. Choosing exquisite fixtures enables a consistent look and it also enhances efficiency. Thus, choosing such components it is possible to create the kitchen that will be aesthetically good and comfortable for the everyday usage and practical for a long time.

Countertops

A worktop made by an artisan using concrete will last a lifetime when used correctly. Reinforcement in construction is done with wire, rebar or glass fiber mesh. The designer can change the colour, edge detail, size, form and finish of it. Stains on the surface are easy to get particularly if placed in a kitchen setting. Hairline cracks may appear over time but they're often nonstructural and only happen due to shrinking from being finished. As these countertops will be used it's unavoidable for this to happen. Acids (found in wine, mustard, vinegars, citrus fruits and other meals) may etch the finished surface if they're not washed off immediately (Binggeli, 2008; Cheng, 2004; Dennis, 2010).

Terrazzo is made from fragments of glass, granite, quartz or marble embedded in a cementitious epoxy or polymer substrate which makes it a composite material that's also poured in place or prefabricated. It was one of the first items to be made from recycled ingredients more than 1,500 years ago and has been used for construction since then too. Because terrazzo is repurposed materials it's recyclable at the end of its life cycle due to its lengthy lifespan (some original floors have been used for more than a millennium). It's resinous as well which means it can absorb liquids like concrete (Binggeli, 2008; Cheng, 2004; Einstein, 2008).

Post-consumer paper is what usually makes up composite countertops since they're impregnated with phenolic resins. Phenolic resins are synthetic substances derived from condensing formaldehyde or phenol-like substances which are created to be used in industrial areas and are water and easily cleanable. The majority of them take up to 350°F heat resistant. It'll darken over time due to oxidation and the sun. They can range in colours from blue to brown and the only daily maintenance needed for it are

wiping it down with a light cloth wash in warm water; nonabrasive cleansers work as well. Sealing it with mineral oil or wax periodically is recommended but make sure not to cut straight across the countertop too (Chyi, 2008; Gibson, 2002; Mandler et al., 2023).

Stone has been at odds with the demand for "green" materials. There are no two stones exactly the same due to their natural, unique beauty; however, it does present an environmental problem being a naturally occurring material that is harvested from the earth and ready for shaping and installation, but stone is heavy. The energy needed to reduce stone to workable "dimension-stone" sizes and then move it around adds up fast. The result of this is a heavy carbon footprint for the material during those two steps alone. Quarrying stone ethically is also an issue because not all quarries treat their workers ethically. Be sure to investigate ordering stone that's local to your job site rather than flying across the world (Itoyama et al., 1995; Platt, 2007; Silva et al., 2021).

The correct stone for a customer is determined by how they'll treat it and what they'll use it for. For instance, granite isn't as prone to etching or scratching as marble. Fossiliferous limestone slabs will quickly develop brown staining if acidic substances are left on them too long (Brown, 2015; Dennis, 2010; Yazıcıoğlu, 2014).

Because soapstone has exceptional thermal properties, it's almost heatproof, costs more than other stones, and is only available in two colors—green and black—it resists staining but gets darker with age (Gibson, 2002; Reis & Adams, 2002).

Increasingly popular for its resistance to staining, durability, and ease of cleaning, engineered quartz surfacing has established itself as a go-to material for kitchen countertops. Numerous producers of quartz countertops have NSF and GREENGUARD certifications. Pre-industrial waste makes up the majority of these products' raw materials—and many contain recycled content.

Polymer-based products such as Corian offer a continuous surface that is ideal for seamless installations in kitchens and bathrooms. The solid surface provides an impervious and anti-bacterial finish that requires minimal maintenance. However, it does cost more than natural materials and can be damaged by heat. Because the sinks can be fitted seamlessly into the worktops, solid surfaces allow designers to create near-flawless installations. Years later, once major repairs have been made by experts, the product can be repurposed and refabricated. One type of synthetic material is polymer (Gibson, 2002; Silva et al., 2021).

Wood countertops are the most environmentally friendly countertop surface and get the strongest reactions. Selecting Forest Stewardship Council (FSC)-certified sustainably harvested wood countertops helps to conserve wood as a natural resource. Choosing durable, dense woods that can withstand sharp knives is recommended; options include hard rock maple, madrone, cherry, bamboo (used as end-grain butcher block), oak or white ash. Wood countertops with burns or stains can be easily restored by simply sanding the area and applying heated mineral oil safe for food use (Cheever, 2014; Davis & Fisher, 2015; Dennis, 2010).

Originally laminate countertops were made with high-VOC papers and adhesives; these synthetic surfaces are coated in plastic. Healthier versions are now available.

Choose a laminate with GREENGUARD certification that is composed of low-VOC or nontoxic glues and paper free of formaldehyde. While laminates are cheap and easy to clean but they can't be repaired, and last 15 to 20 years and cannot be recycled. When using laminate the best options are the ones made with low-VOC, solvent-free or water-based adhesives and non-urea-added formaldehyde (NUAF) (Gibson, 2002; Pinkus, 2017).

Cabinetry

Cabinets and appliances are two of the costliest items in a kitchen remodeling. Budget constraints often cause clients who originally prioritized sustainability above anything else to stray from their intentions when it comes time to choose materials for these items (Cheever, 2014). These are the best practices for producing green cabinetry:

- **Drawer boxes**: Use solid wood drawer boxes, not particle board. It is recommended to use a wood which is FSC certified. Sturdy and fast-growing materials such as poplar and alder are also excellent selections for drawer boxes.
- **Hardware:** Look for domestically manufactured hardware. Even though drawer runners and closures are hidden, the quality of them is sensed every time the drawer is opened.
- **Hinges and pullout panels.** Seek out FSC-certified woods and veneers. If you're working with painted surfaces, ask about low- and no-VOC paint.
- **Finishing:** If you're dealing with a cabinet builder, specify low- or no-VOC paints, stains, and finishes.

- **Use locally produced wood:** Transporting wood requires less fossil fuel when it's made nearby. This both strengthens the local economy and adds a distinctive flavor to your project (Davis & Fisher, 2015).

Appliances

Buying appliances locally has a much smaller carbon cost in transport than an appliance produced abroad (Tiller, 2008). Designers must be adequately informed about appliances in order to advise clients properly. To determine which appliance options are greenest (and not just energy efficient), it is recommended to look into products by ENERGY STAR, and he EPA's WaterSense program's consumer Reports (Foster et al., 2012; Gould, 2009).

Magnets are used in induction cooking. A magnetic field is produced between the pan and the cooking element. Because the cooking element itself doesn't get hot, less energy is used up and wasted. Pots and pans with ferrous materials are necessary for this kind of electric cooking. Compared to gas, it has three advantages:

1. Safety: Because the cooktop never gets hot, there's no residual heat, which means less heat left in the pan to affect the surrounding air after it's been taken off the cooking surface. A home with young children or one where there's a family member with dementia or developmental impairments would benefit a lot from this feature. Additionally, many induction cooktops have a lock-out feature for added safety.
2. Energy Efficiency: An induction cooktop requires directly transfers more energy to the food than any other cooking surface. Coil electric usually uses around 20% less energy.

3. Indoor Air Quality: Natural gas-fueled cooktops produce pollutants when they're used, unlike induction cooktops. Gas cooktops for commercial use need added venting because of this fact. If you have any immune deficiencies or environmental sensitivities, an induction cooktop is highly recommended (Ha, 2007; Knott, 2010).

Fixtures and Fittings

The most used appliances in the kitchen are the sink and faucet, followed by the refrigerator, but sinks can have a high embodied energy content because of recycled content, water flow and where the product was made. It is recommended to find models made locally to help reduce carbon footprints (Whiting et al., 2023).

A standard faucet is thirty percent less efficient than a WaterSense faucet. The main way used to increase the efficiency is by aerating the water through the faucet's stream of water. The maximum flow rate of a faucet with a WaterSense designation is 0/75 liter per minute. As previously noted, metals and metal coatings have a large environmental impact. Thus, it would be best to choose the most durable model. (Council , 2021; ERİK, 2021; Shuble, 2022).

4.4 Guidelines

In the following text, a table has been devised to summarize the presented guidelines based on kitchen components, sustainable goals, criteria and considerations. In addition, this table integrates what has been said in chapter 2, 3 and 4 in order to increase the practicality of the guideline.

The guide comprehensively covers the various aspects of building a sustainable kitchen, including instructions for creating an environmental-friendly space, to the essential factors and important details required for implementing a sustainable kitchen.

Table 2: The guideline

	Kitchen Elements	Guide	Sustainable Criteria	Sustainable Goals	Sustainable Considerations
Sustainable Construction	Wall Finishes	Use non-toxic and durable wall finishes	Environmental Aspect: Renewable materials. **Human Aspect:** Indoor Environmental Health.	Creating healthy environments. Improving the longevity.	Choose sustainable materials. Indoor air quality.
	Window Specification	Choose Low-E and Low U-factor glass. Choose frame according to weather and climate	**Environmental Aspects**: Carbon Footprint, Energy efficiency. **Human Aspect:** Indoor Environmental Health	Improving energy optimization, Improving the longevity, creating healthy environments (Thermal comfort)	Choose sustainable Material. Thermal Isolation.
	Flooring	Use renewable materials	Environmental Aspect: Renewable Materials	Reducing environmental degradation.	Choose sustainable materials
	Sealers	Use eco-friendly, non-toxic and durable sealers	**Environmental Aspect:** Outdoor Environmental Health. **Human Aspect:** Indoor Environmental Health	Reducing environmental degradation. Creating healthy environments. Improving the longevity.	Choose sustainable materials
	Heating and Cooling	Choose energy efficient HVAC systems (based on energy rating systems) according to the climate and weather. Always consider radiant heating, zonal heating, heat pumps and energy/heat recovery ventilators as sustainable options for their appropriate weather.	**Environmental Aspect:** Carbon Footprint. Energy Efficiency. **Human Aspect:** Indoor Environmental Health	Improving energy optimization. Creating healthy environments.	Invest in energy-efficient appliances. Indoor Air Quality. Utilization of cutting-edge technologies for sustainability.
	Water Conservation and Distribution Systems	Use systems with hot water on demand.	**Environmental Aspect:** Carbon Footprint. Energy Efficiency.	Improving energy optimization	Invest in energy-efficient appliances.
		Point of use water heaters	**Environmental Aspect:** Carbon Footprint. Energy Efficiency.	Improving energy optimization	Invest in energy-efficient appliances.
		Drain water heat recovery system (DHR)	**Environmental Aspect:** Carbon Footprint. Energy Efficiency.	Improving energy optimization	Invest in energy-efficient appliances.
		Harvest Rainwater	Environmental Aspect: Resource Efficiency	Reducing environmental degradation	Water Conservation
	Deconstruction	Reusing as much material as possible in order to achieve optimal and highest use	Environmental Aspect: Resource Efficiency	Reducing environmental degradation. Reducing waste.	Sustainable Economy. Waste reduction.
	Green Space Planning	Space planning for recycling and composting	Environmental Aspect: Resource Efficiency	Reducing environmental degradation. Reducing waste. Increasing the benefits of designed environments.	Space Planning. Waste Reduction.

	Kitchen Elements	Guide	Sustainable Criteria	Kitchen Elements	Guide
Indoor Air Quality	Kitchen Ventilation	Use appropriate HVAC system by consulting experts. Consider a makeup air system in your planning.	**Environmental Aspect:** Energy Efficiency. **Human Aspect:** Indoor Environmental Health	Improving energy optimization. Creating healthy environments.	Invest in energy-efficient appliances. Indoor Air Quality. Utilization of cutting-edge technologies for sustainability.
	Indoor Air Pollutants	Use materials and tools to decrease the common indoor air pollutants	**Human Aspect:** Indoor Environmental Health	Creating healthy environments	Indoor air Quality
Appliances and Fixtures	Countertops	Use materials for countertops that minimize the indoor air pollutants, maximize the longevity and enables recycling or reusing.	**Environmental Aspect:** Embodied Energy, Carbon Footprint, Renewable Materials, Product Circularity. **Human Aspect:** Indoor Environmental Health	Reducing environmental degradation. Creating healthy environments.	Choose sustainable materials. Indoor air quality. Sustainable Economy.
	Cabinetry	Use locally produced wood with non-toxic finishing and FSC-certified hardware.	Environmental Aspect: Renewable Materials. **Economic Aspect:** Support Local Businesses **Human Aspect:** Indoor Environmental Health	Reducing environmental degradation. Creating healthy environments. Supporting local businesses.	Choose sustainable materials. Space Planning. Sustainable Economy.
	Appliances	Use safe, energy efficient and non-toxic appliances	Environmental Aspect: Energy efficiency. **Human Aspect:** Indoor Environmental Health	Improving energy optimization. Creating healthy environments.	Invest in energy-efficient appliances. Indoor Air Quality
	Fixtures and Fittings	Use sink and faucet with low embodied energy and water saving systems.	**Environmental Aspect:** Embodied energy, Resource efficiency.	Reducing environmental degradation.	Choose sustainable materials Invest in energy-efficient appliances Water Conservation Sustainable Economy

Chapter 5

CONCLUSION

In our world the increase in global population and their demands resulted in consuming the limited resources of our world in a rather fast manner, faster than it can be replaced. Thus, it is now very important to consider the environmental, social and economic impacts of all our actions and their effects on the coming generations and not only the human beings but all the living creatures on the earth. Thus, sustainability as an approach that aims to fulfil the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Report) is now an important concept in all fields including interior architecture. Interior architects should be aware of the consequences of their actions and decisions on the environment now and in the future. The same concerns are valid while designing kitchens, and particularly residential kitchens.

This study aims to develop guidelines for interior designers to help them achieve sustainability while designing residential kitchens. The lack of practical recourses related to this issue is one of the main drives of conducting this study.

The proposed guideline is a result of a comprehensive literature review on sustainability and its relationships with architecture, interior design and kitchen itself. The elements of sustainable kitchen have been extracted from relevant literature and a practical guideline for designing sustainable kitchens has been devised accordingly.

Students, educators and practitioners can employ this study to access the most important aspects of environmentally sustainable kitchen design. Designing a sustainable kitchen can end up in almost infinite scenarios, however, this research can introduce initial pathways for starting a journey towards designing an effective environmentally friendly kitchen space.

Current research emphasizes crucial importance of considering sustainability in interior design of the residential kitchens, that commonly consume important resources. In this research the literature review based knowledge aims to provide useful information to develop sustainable practices in the residential kitchen designs.

Kitchen is the area where various sustainable measures can be incorporated because it is a highly utilized space of a house, consumes large amounts of resources, and directly influences the overall sustainability of a home. Key findings of the study involve a concern with the use of sustainable and healthy materials. On the other hand, a choice of efficient appliances and lighting will help to make long term savings. Further, techniques like use of less water-using fixtures and utilizing water recycling mechanisms should be adopted in order to design sustainable kitchen. The measures for having better air quality and better indoor air are also discussed. Besides, the basic considerations to have a proper space planning as key measures to enhance the functional arrangements of items in a kitchen are mentioned.

The practical guideline of the study elaborating the structural characteristics and elements to be taken into consideration concerning the construction of sustainable residential kitchens is a useful instrument for interior designers, their teachers, as well as ordinary homeowners. These guidelines make designers able to achieve low

impacted homes, enhance healthy living, and encourage global change towards sustainable living. Other benefits of sustainable kitchen design as indicated in the guideline include the economic and the social benefits. Choosing to work with local companies and suppliers enables the designers to improve on the interaction of communities to promote economic growth.

There is a need to encourage realization of more studies which incorporate social and economic aspects of sustainability in the design of kitchens. Future studies should therefore extend this work into more inclusive studies on enhancing the sustainability of residential kitchen by including other aspects of social and economic sustainability, new technologies and design approaches.

In conclusion it is possible to state that the availability and utilization of the sustainable ideas in the residential kitchen design is not the trend, but the question of future and health of the world. Following these guidelines helps the interior architecture contribute in the creation of a more sustainable future.

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auch also durch Anflug und Wiederwachs des so wohl guten und schleunig anwachsend, als andern gewüchsig-und nützlichen Holtzes, ganz öde und abgetriebene Holtz-Ländereyen, Plätze und wiederum .... *(No Title)*.

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