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Investigating Regenerative Ideation within Sustainable Development Goals

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Abstract: The rapid deterioration of ecosystems and the growing impacts of climate change, which is expected to increase the average global temperature by 3–6 degrees Celsius by 2100 according to The Paris Agreement, reveals that sustainability is no longer an adequate solution to these ongoing challenges. As a result, a paradigm shift toward a more evolutionary approach has recently become a demand, where regenerative concepts have rapidly replaced current sustainable practices. Rather than minimizing human impacts on the environment, regenerative ideation aims to generate more than consume and tackles many shortcomings of conventional sustainability. Therefore, the study attempts to provide an answer for the debate on how far can regenerative ideation go beyond current sustainability, and to what extent does this concept deliver on the UN's Sustainable Development Goals (SDGs). Therefore, the study aims first to develop regenerative development goals that adopt an integrated approach and secondly to assure their compliance with the UN's SDGs. The study employed a qualitative methodology and the case study approach to examine the applicability of the proposed principles. The findings provide clear criteria for architects and urban designers to use in spreading regenerative design to create a more responsible built environment. The study recommends further research on creating regenerative development and design metrics and indicators for practicing the concept within the built environment.

Keywords: regenerative design; regenerative sustainability; sustainable developments goals; regenerative development goals; ecological sustainability

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1. Introduction

Since the 17th century, sustainability has governed the policies of all nations seeking to achieve a sustainable future based on the incorporation of social, environmental, and economic aspects. However, the current pace of climate change, high rates of natural resource depletion, and the high increase of the world population, which is estimated to grow by 2 billion to 9.7 billion people by 2050 [1–3] make sustainability insufficient for addressing those ongoing global challenges [4]. This shortcoming is a result of the imbalance between reducing the negative impact of the built environment and the accelerating rates of environmental degradation. Furthermore, for many decades, sustainability embraced a mechanistic worldview that separated human beings from their natural context, [5] while the global concept embedded a generalization regardless of the particularity of context [6]. As a result, ecological sustainability emerged to cover this shortcoming of the mechanistic worldview [7]. However, it still works with fragments of systems rather than working with whole systems [8]. The world has realized the urgent need for an evolutionary concept that embraces a comprehensive worldview and aims to manifest the prosperity of living systems in a fully integrated system. Many scholars advocate that the regeneration paradigm holds great promise towards achieving this holistic sustainability through reconceptualizing the co-relationships between human, technological, economic, social, ecological, and political systems [5,7,9–13]. On the other hand, the United Nations General Assembly has developed the 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDGs). It has become the global vision for surviving the world and human well-being. Therefore, many governments have recently adopted policies for the gradual implementation of the SDGs [14]. To the best of the authors' knowledge, no study was found that developed regenerative development goals within the UN's SDGs. Therefore, the significance of the current study lies in bridging this knowledge gap by deeply understanding regeneration ideation within the built environment, its motivations, definitions, and principles. Accordingly, the current study is aimed at setting regenerative development goals (RDGs) to tackle the shortcomings of traditional sustainability, aligning with the UN's SDGs. Two case studies were selected: SEKEM village in Egypt and Dubai Sustainable City in the United Arab Emirates, to investigate the applicability of the developed RDGs. The results offer fundamental criteria for spreading regenerative development at different scales of the built environment. The study helps raise awareness toward adopting a creative and integrated approach to sustainable buildings, communities, and cities.

2. Research Methodology

The study attempts to answer the following questions: How far does regenerative ideation go beyond current sustainability to provide a holistic and integrated approach? To what degree does this evolutionary concept deliver on the UN's SDGs in the 2030 agenda? The study adopted a qualitative and quantitative approach besides the case study method and the comparative analysis. The study begins with reviewing related literature, which relied on a systematic web-based search in Scopus and on the Web of Science. The search terms included: regenerative development, regenerative design, and regenerative architecture to understand the state of the art. Based on this literature review, the study proposed regenerative development goals and then used the comparative analysis to compare these goals with the UN's SDGs to measure the degree of their compliance and check their validity theoretically. In the analytical study, we investigated how far RDGs were manifested in the two selected case studies. The case study method was used to examine the applicability of proposed RDGs at different built-environment scales and to define the limit for generalizing the findings. Therefore, the study selected SEKEM village in Egypt to represent the neighborhood scale and Dubai in UEA to represent the city scale to stand on various strategies and techniques for applying regenerative development. SEKEM village was also selected because it is regarded as a unique Egyptian model for sustainable development with international recognition, as shown by winning the Alternative Nobel Prize in 2003 and the Business for Peace Award in 2012. Dubai Sustainable City was selected as a second case study where many of the sustainability strategies have been significantly implemented. Finally, the results obtained from the study provided comprehensive regenerative development goals and different techniques of application. Figure 1 shows the study's structure.

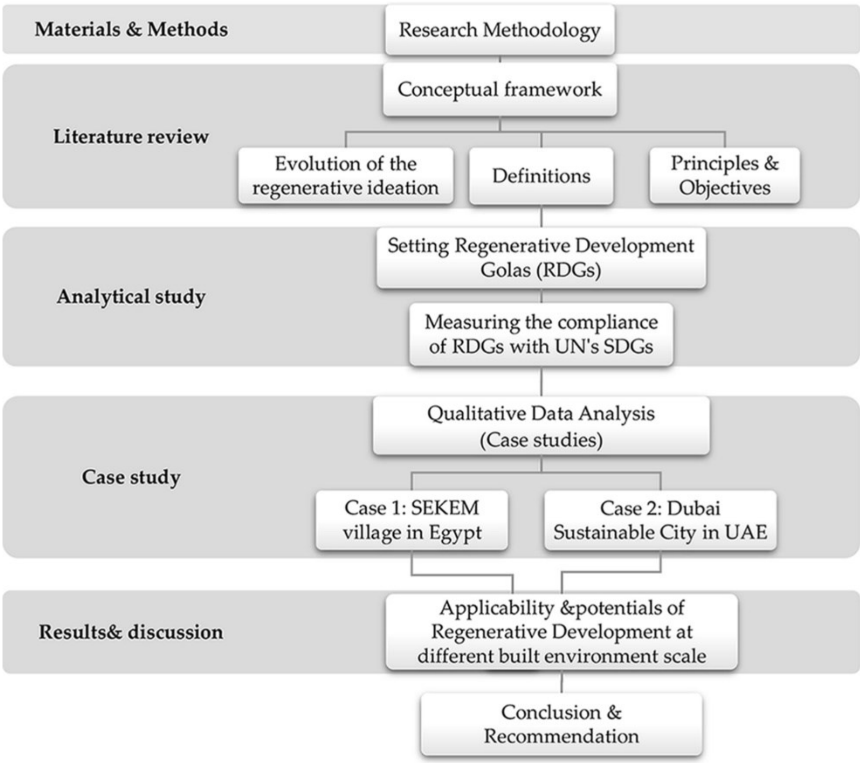


Figure 1. The study's structure.

3. Conceptual Framework

3.1. The Ecological Versus the Mechanistic Worldviews of Sustainability

The scientific revolution of the seventeenth and eighteenth centuries resulted in a radical shift in the medieval paradigm, from the organic and spiritual universe to the mechanistic paradigm. In this new paradigm, the world is seen as a machine where the system governs all aspects of modern human life and nature, like a mechanical system, is finite, linear, and organized by laws. It further saw human beings as an independent and predominant part of nature [15]. Between 1950 and 1960, Eugene and Howard Odum developed the groundwork for ecology's modernization as a science based on the central notion of the ecosystem as nature's basic organizing structure [16]. Their book, "Fundamentals of Ecology", paved the way for the development of the ecological worldview, which saw nature as a dynamic organic web in which human beings are an integral part, and all entities evolve following their context [12].

3.2. Regeneration Ideation versus Sustainability

Cole [10] and Zhang et al. [7] distinguished between two approaches to sustainability: technological sustainability, which emphasizes the anthropocentric view, considers human beings the center of the universe, and makes more efficient technical and engineering approaches; and ecological sustainability, which situates the existence of human beings within a wider natural setting and has the significance of allowing ecological systems to survive and adopting less harm or net-zero solutions to decrease the negative impacts of human beings. The rapid depletion of natural resources due to climate change reveals that ecological sustainability has become insufficient in addressing those ongoing global challenges, thus sustaining the future of human life and the ecosystem [17]. In the last decade, the world has realized the urgent need for a radical shift in the predominant paradigm of sustainability toward a more holistic, inspiring, and motivational approach [5]. The ecological worldview and co-evolutionary sustainability have driven the emerging trend of regenerative development as the next wave of sustainability [18].

3.3. Emergence of Regenerative Development and Design

Mollison and Holmgren coined the term "permaculture" in 1978, referring to permanent agriculture as the first ecological design system that emulates natural systems and embraces the regenerative notion to support the design of human homes and food production systems [19]. Robert Rodale coined the term "regenerative" in agriculture in 1980 to describe his methods for reviving soil life to provide wholesome food [20]. Rodale's ideas served as a guide for later regenerative methodology formulation and application [16]. As interest in ecological design methods grew in the middle of the 1990s, the regenerative sustainability paradigm evolved as a coherent strategy [15]. *Regenerative Design for Sustainable Development*, the first thorough articulation of and handbook for regenerative design, was published in 1996 by John Tillman Lyle. In it, Lyle outlined six guiding principles and techniques for a design technology intended to undo the environmental harm brought on by what he called "industrial land-use practices." Advances in network theory and living systems theory over the past 50 years have formed the basis of regenerative development approaches and practices [15]. Figure 2 shows the evolution of regeneration ideation.

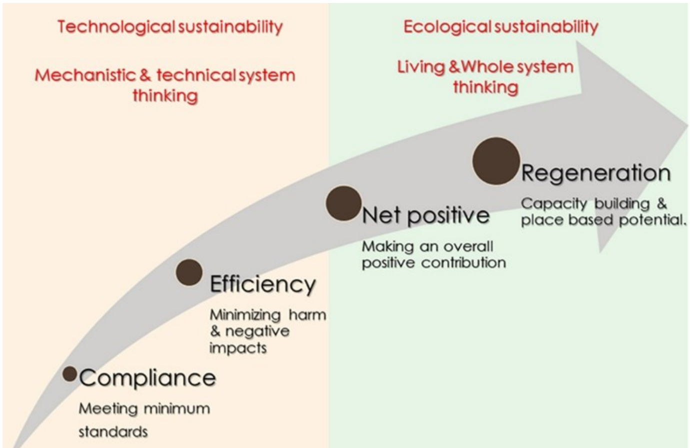


Figure 2. Evolution of regenerative ideation.

3.4. Definition of Regenerative Development

In the past ten years, there has been a spike in interest in regenerative development and design among academics and professionals, which has aided in the development of the underlying assumptions and ideas. The regenerative design was defined by Jenkin and Zari [21] as linear systems of throughput flows that need to be changed to cyclical flows at sources, consumption hubs, and sinks. According to their theories, regenerative design is the intentional planning of entire ecosystems, with individuals, human developments, social structures, and cultural issues included as integral parts of the whole. According to Haggard [22], Zhang et al. [7], and Gibbons [5], the creative potential of regenerative development necessitates a fundamental paradigm shift: from viewing the site as a collection of discrete pieces to adopting an integrated and holistic perspective, where the site is viewed through a regenerative lens as a web of connected dynamic processes that continuously create and recreate buildings, neighborhoods, urban areas, and regions. Regeneration is defined by Van der Ryn and Cowan [18] as a type of healing and rejuvenation that embodies the numerous opportunities for civilization to coexist with nature. It restores a lost plenitude in addition to preserving and safeguarding. For the earth to once again be suitable for human habitation, Du Plessis [13] defined regenerative sustainability development as a significant transition from a mechanical to an ecological worldview. Regenerative sustainability, according to Mang and Reed [11], Cole [10], and Zhang et al. [7], is built on a co-evolutionary, a cooperative interaction between natural systems and people that aims to create long-term social and natural capital to accomplish a comprehensive objective with long-term co-benefits. Regenerative development is a place-based development and design process that aids living systems in acquiring the capacities they require to grow in complexity, diversity, ability to support all species, and evolutionary potential, according to Gibbons [5]. It addresses the core causes of unsustainability, offers comprehensive alternatives based on how healthy living systems work, and is intrinsically more exciting and motivating. The place dimension was also stressed by Haggard [22], Benn and Mang [15], and Bonyad et al. [19], who viewed architecture as a built component of a place and context. For the building to endure, its setting is necessary, and the context benefits from the building for its evolution. Regenerative design is "the activity of engaging the natural world as the medium for and generator of building", according to Littman [23]. In regenerative architecture, he claimed, the productive output from the system must be larger than the net input of resources into the system. The plan ought to produce more food, potable water, and electricity than it uses. The necessity for a holistic understanding of the ecosystem as a regenerative design based on the idea that the built environment integrates with the natural environment was stressed by Chidinma and Omoyeni [24]. According to them, the goal of regenerative design is to develop a system that resembles a closed-loop life cycle in which all entities are interdependent. Developed from a thorough literature review, regenerative development is an approach to planning and building that fosters a co-evolving and harmonious relationship between people, their environment, and the ecosystem. It also encourages all system components to evolve, regenerate, and produce more than they consume to improve both the ecosystem's health and people's quality of life.

3.5. Principles of Regenerative Development and Design

Advances in living systems theory and ecology formed the basis for developing the strategies and practices of regenerative development and design and helped many authors formulate the principles of regenerative development and design. Table 1 summarizes the most significant authors' attempts.

Table 1. Various attempts of theorists for formulating principles of regenerative development and design.

Year	Developer	Principles of Regenerative Development and Design
1993	The Todds' Principles of Ecological Design [25]	The living world is the template for all design Following nature rather than rejecting Achieving biological balance Imitating bioregionalism Using renewable energy Coevolution with nature Sustainability through integrating whole systems Promoting the restoration of the earth Following a sacred ecology
1994	John Tillman Lyle [26]	Effectiveness as the end target Closed-loop system Integration of human developments with natural processes Interdependence between different substances Multiple approaches to the same target
2000	Hannover Principles by William McDonough [27]	The coexistence of human beings and nature in a healthy, supporting, dynamic, and sustainable manner Understanding the interrelationship of the built and natural environments Spiritual and physical awareness Accountability for the effects of design decisions on human well-being Safe materials of long-term value Eliminate waste by improving the products' whole life cycle and processes. Natural energy flows Understand the limits of design Nature as a model and guide

Table 1. *Cont.*

Year	Developer	Principles of Regenerative Development and Design
2005	The Five Principles of Ecological Design by Van Der Ryn and Cowan [18]	Solutions Emerge from the Environment Ecological Accounting Influences Design Design with Nature All humans are designers Make Nature More Apparent
2009	The Nine Principles of RA by Littman [23]	Whole design integration Integration into the Landscape Principle of Intelligent limits Principle of Concentration on Space Principle of Intelligent Construction Principle of Bold Ecology Principle of Community Experience of Place Principle of Culture
2012	Ray Cole [10]	Supporting the constructive coevolution of human and natural systems, versus designing things positively supporting design processes versus building as a product The building is crucial in establishing greater degrees of order Constructive interactions and innovative synergy with neighboring buildings and other natural systems
2013	Mang and Reed, Regenesis Group [11]	Recognizing and visualizing the direct correlations to place Regenerative potential must be locally created and incorporated Partnering with Place Progressive harmonization between human and natural systems

4. Developing Regenerative Development and Design Goals (RDGs)

The study proposed nine regenerative development and design goals (RDGs) driven by a literature review of various principles, potential, and definitions, as shown in Figure 3. These goals are described and compared with the UN's SDGs in Table 2.

Figure 3. The proposed Regenerative Development Goals (RDGs).

Table 2. The proposed RDGs and their description compared with UN's SDGs.

RDGs	Description	UN's SDGs
RDGs 1. Integration of human, place, nature, and ecosystem	All systems and their elements are accommodated for and incorporated into the whole system design in a healthy, supportive, and co-evolutionary relationship	**SDG 1–SDGs 16**
RDGs 2. Energy management	Net-positive energy and renewable energy production	**SDG 7 Affordable and Clean Energy** **SDG 13 Climate Action**
RDGs 3. Zero Carbon	Adopting a carbon-neutral approach	**SDG 13 Climate Action**
RDGs 4. Water management	Net-zero water or positive water purification	**SDG14 Life Below Water:**
RDGs 5. Material and Resources Management	Healthy (nontoxic, biodegradable, and sustainable materials) and safe materials	**SDG 12 Responsible Consumption and Production:**
RDGs 6. Zero waste	Closed-loop with net-positive waste management	**SDG 3 Good Health and Well-Being** **SDG 12 Responsible Consumption and Production**
RDGs 7. Health and well-being	Increase the quality of life and improve the overall health and well-being of individuals, communities, and societies	**SDG 2 Zero Hunger** **SDG 3 Good Health and Well-Being**
RDGs 8. Regenerative economy	Fair and equitable, well-being economy	**SDG1** **SDG 8 Decent Work and Economic Growth** **SDG 12 Responsible Consumption and Production:**
RDGs 9. Culture and community	Inclusive and equitable societies, regenerative cultural design, and identity	**SDG 4 Quality Education** **SDG 5 Gender Equality**

5. Analysis of The Two Case Studies against RDGs

The current study chose SEKEM village in Egypt to represent the neighborhood scale and Dubai Sustainable City in the United Arab Emirates to represent the city scale. They were analyzed against the nine RDGs to examine the applicability of the proposed RDGs at different built-environment scales.

5.1. Case Study 1. SEKEM Village

SEKEM is an Egyptian initiative created in 1977 in the Egyptian desert by Dr. Ibrahim Abouleish. It turned 70 hectares of desert located 60 km northeast of Cairo, as shown in Figure 4, into a showcase example of sustainable agriculture and a healthy ecosystem. Abouleish's vision was to meet the contemporary challenges by achieving sustainable development where each human being may develop his capabilities; where humanity coexists in social forms that represent human rights; and where all economic activities integrate with ecological and ethical values [28–31]. Dr. Abouleish has received over 30 international awards and honors for his initiative, the most prestigious of which are: the Arab Academy of Banking and Financial Sciences Award for Outstanding Social Entrepreneurship in Jordan in 1988; and the alternative Nobel Prize for Right Livelihood Award in Sweden in 2003 for its successful corporate and socioeconomic model [29,31]. For 30 years, SEKEM village expanded to include successful commercial business ventures as well as cultural and social institutions, including a kindergarten and elementary school, a medical center, several workshops and vocational organizations, an amphitheater, and a residential complex that houses the Abouleish family and some of SEKEM's employees [10].

Figure 4. SEKEM village location.

5.1.1. RDGs 1. Integration of Place, Nature, and Ecosystem

SEKEM adopts a place-based design approach not only to reduce the negative environmental impact but also to contribute to a better and healthier state of the place, people, and nature in an integrated and holistic view through the following:

- SEKEM's approach to sustainable development combines four aspects of life: the economy, society, culture, and ecology into a holistic totality in which all elements are independent and interconnected [28–32]. It has developed 16 goals that emerged from these four pillars to realize Abouleish's vision of sustainable development [28]. SEKEM established several institutions to manage each sector, including the SEKEM Development Foundation (SDF) for cultural life, the SEKEM Holding for economic life, the Egyptian Biodynamic Association (EBDA), SEKEM Agriculture for ecological aspects, and the SEKEM Future Council for social life [33,34], as shown in Figure 5.

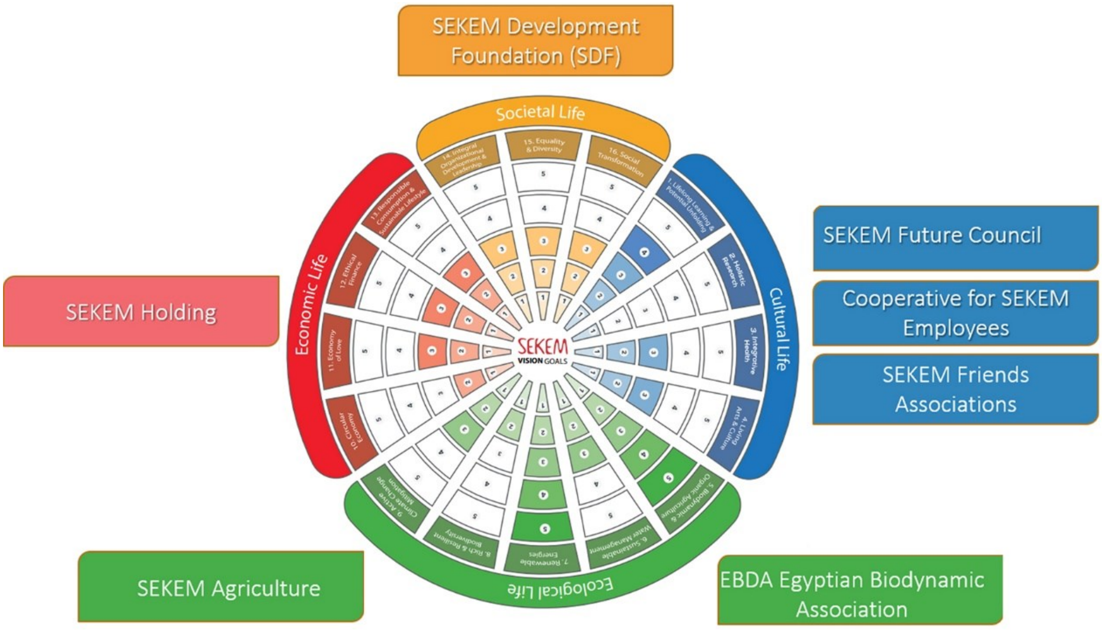


Figure 5. SEKEM village location. SEKEM's sustainable development flower shows the four main pillars and their 16 goals incorporated with the relevant institutions. Source: SEKEM sustainability report [35].

- SEKEM's approach to integrating with nature is reflected in adopting organic and biodynamic agriculture that enhances soil fertility and conserves the ecosystem's biodiversity. It has implemented a new plant protection system for cotton, which has resulted in a prohibition on crop dusting throughout Egypt. By 2000, pesticide usage in

Egyptian cotton fields had dropped by more than 90% [29]. SEKEM's farms promoted animal health, welfare, and genetic diversity in wildlife and husbandry [28]. The other related projects were: the Knowledge Hub for Organic Agriculture in North Africa project and sustainable intensification of food production through resilient farming systems [35]. Figure 6 demonstrates the indicators of ecological life in SEKEM. See Figure A1 for more details.

Figure 6. SEKEM's ecological life. Source: SEKEM sustainability report [35].

5.1.2. RDGs 2. Energy Management

SEKEM seeks to reach 100% of the renewable energy share by 2027. Therefore, it established "EcoEnergy", which is authorized to use renewable energy to provide electricity to all SEKEM's buildings [33,35]. Its activities include:

- Developing a multi-generation solar power plant for the medical center [36];
- Installing concentrated photovoltaic thermal (CPVT) in Heliopolis University to supply its buildings with electricity and thermal hot water [37], as shown in Figure 7;
- SEKEM also implemented the "Greening the Desert" project with renewable energy and developed biodiesel fuel at Heliopolis University [35]. Indicators of energy management are shown in Figure A1.

Figure 7. Concentrated Photovoltaic Thermal (CPVT) in Heliopolis University. Source: Author.

5.1.3. RDGs 3. Zero Carbon

Since May 2007, SEKEM has established a composting facility for producing high-quality compost as a method used to reduce carbon emissions. SEKEM avoids about 60,000 tons of CO_2e per year and utilizes these carbon credits to offset the carbon emissions of several agricultural products [38]. According to SEKEM's sustainability report [35], CO_2 was sequestered more than emitted in 2021, and the total emissions of CO_2 decreased by 470 tons compared with 2020 to make SEKEM a carbon-negative organization in 2021. Figure A1 shows indicators of the zero-carbon goal.

5.1.4. RDGs 4. Water Management

Using aquaponics in organic food production has led to water efficiency, using up to 90% less water than conventional agriculture. In addition, SEKEM and Heliopolis University developed a wastewater management system that focuses on applying low-cost techniques such as natural treatment plants and water recovery through humidity condensation. It additionally implements a saltwater usage project. SEKEM finally succeeded in recycling and reusing all its wastewater [35]. Figure A1 shows indicators of water management goal.

5.1.5. RDGs 5. Material and Resources Management

The evidence of achieving this goal is demonstrated in SEKEM's sustainability report [35] as follows:

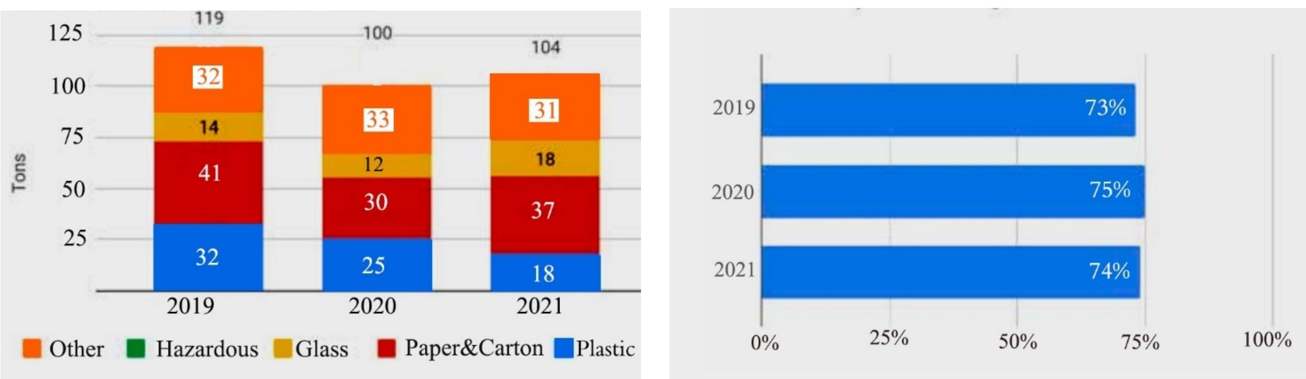
- SEKEM uses healthy and safe materials in its agricultural activities and industries. It produces several organic products based on organic fertilizers that are safe for human health, thus increasing awareness of the consumption habits of employees and members of the surrounding community.
- SEKEM recycled all its organic waste into a valuable input for land reclamation processes.
- SEKEM reused agricultural waste such as tree trunks and leaves as outdoor furniture for kids' play areas in SEKEM school.

5.1.6. RDGs 6. Zero Waste

According to SEKEM's vision 2027, it aims to be a waste-free village. It also spreads the concept throughout the Egyptian community. It applied proper waste management through the following projects [28]:

- Fully monitoring, sorting, and recycling the waste produced by the companies inside SEKEM;
- Recycling all organic waste into compost;
- Having its pharmacy research its waste production and develop methods to deal with it;
- Reusing waste in the fine arts;
- Implementing better waste collection with economic incentives;
- Implementing zero-waste research.

Figure 8 shows the waste production from 2019 to 2021, as mentioned in its report [35]. Indicators of the zero-water goal are shown in Figure A1.



(a) (b)

Figure 8. Zero-waste relevant indicators: (**a**) non-organic waste by type. (**b**) Share of recycled non-organic waste. Source: SEKEM sustainability report [35].

5.1.7. RDGs 7. Health and Well-Being

SEKEM's responsibility for human health and well-being is reflected in:

- Adopting organic and biodynamic agriculture protects thousands of people from the health damage of long-term pesticide exposure. It also enhances soil fertility and stability, positively affects the ecosystem's diversity, and produces healthy products [39,40];
- Recycling and reusing all organic waste as a fertilizer protects the environment from air or soil pollution and greenhouse gases [39,40];
- Providing healthcare at the medical centre to the employees and the local community, and additionally providing awareness programs related to human health for rural people [29,34,39].

5.1.8. RDGs8. Regenerative Economy

SEKEM's holding of companies supports local economies through its supply chain. It guarantees fair prices and long-term cultivation contracts to farmers to protect them from the rapid change in the market. It has taught 477 Egyptian farmers biodynamic agricultural methods, which are used on around 4600 acres of land [30,39]. It also applies circular economy by adopting proper waste management, as mentioned in RDGs 6.

5.1.9. RDGs9. Culture and Community

The SEKEM initiative strives toward human and community development. As a result, it founded SEKEM Development Foundation (SDF) in 1984 to comprehensively enhance the lives of its employees and the local community while raising their cultural awareness. The SDF established the following institutions to fulfill its mission [30,31,33,34,39].

- SEKEM kindergarten was established in 1985 for employees' kids and the surrounding community.
- The SEKEM School, launched in 1989, provides a creative approach to learning by emphasizing the development of its pupils' social, cultural, and intellectual abilities besides offering aesthetic and art courses.
- The vocational training center, which started in 1997, offers a three-year curriculum designed to provide youth with relevant professional skills. The curriculum emphasizes the principle of doing while learning. The training fields include industrial mechanics, carpentry, textile production technology, and agricultural machinery. Since 2006, about 1000 students have graduated from this center.
- SEKEM Environmental Scientific Center provides its local community with interactive science classes on environmental themes.
- In 2012, SEKEM built Heliopolis University, a not-for-profit university specialized in sustainable development in different fields, including medicine, agriculture, arts, economics, and engineering. It also provides knowledge transfer opportunities to farmers, workers, and the community.
- SEKEM enhanced its employee engagement through the art department and training that aims at personal development by exploring their potential.
- The other applications of this mission are as follows:
- Enhancing and strengthening the value of equality through the daily meeting circles, where all employees come together to talk about their accomplishments. This meeting circle symbolizes unity and equity value [31];
- Entitling its staff to discounted education expenses for their children at SEKEM's schools [32];
- Providing free courses for illiterate employees [32];
- Developing the Special Education Program in 1989, which aims to equip students with special needs with multiple fundamental skills in reading, writing, and arithmetic as well as cooking, landscape care, painting, music, and religion courses [34,39]. Figure 9 shows the socio-cultural life indicators.

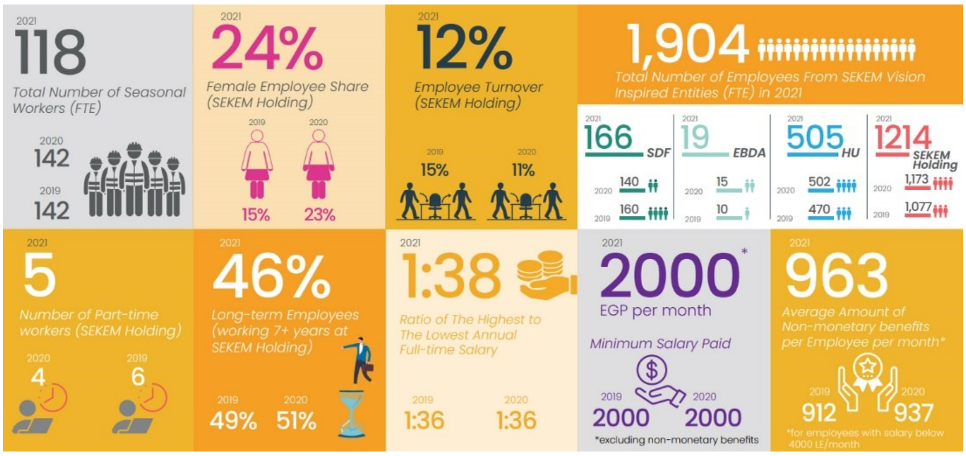


Figure 9. Socio-cultural life indicators. Source: SEKEM sustainability report [35].

Figures A1 and A2 show more details.

5.2. Case Study 2: Dubai Sustainable City

Dubai has always been in the spotlight, and in a short amount of time, it rose to prominence as a leading metropolis with a wise government. This is manifested in the Dubai Sustainable City (DSC), where the Sustainable Development Goals have been adopted and various sustainability solutions have been implemented successfully. Diamond Developers built the city, which provides a healthy, dynamic, and sustainable environment for its citizens. It is a 5,000,000 sq. ft. plot of land in Dubai, 20 min from the Burj Al Arab Hotel [41]. As depicted in Figure 5, it consists of a residential area, a sustainable plaza, urban farming, parking areas, a green school, and a mosque, as shown in Figure 10.

The investigation of RDGs application in Dubai's sustainable system is shown in the next section.

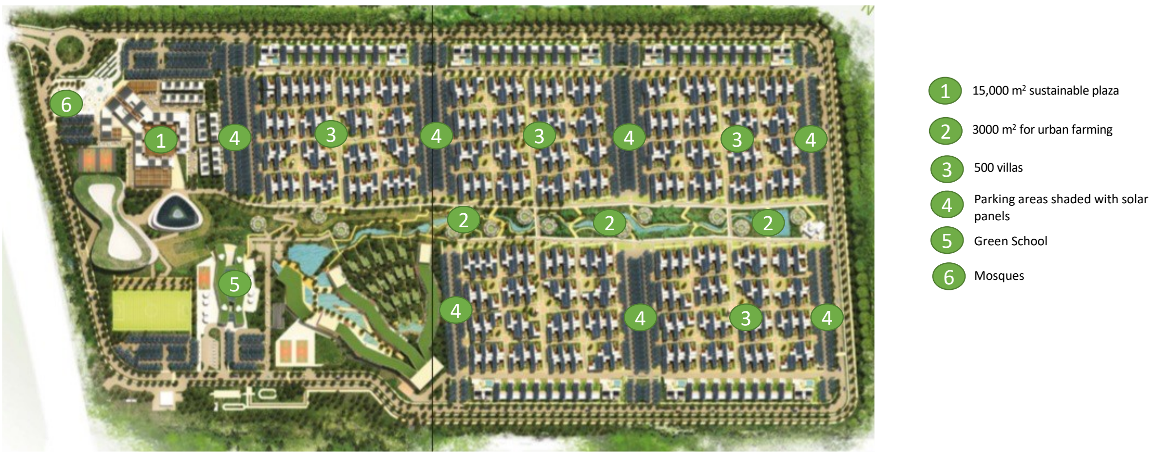


Figure 10. Dubai Sustainable City location. Source: The sustainable city [41].

5.2.1. RDGs 1. Integration of Place, Nature, and Ecosystem

The four pillars of sustainability have been implemented into Dubai's Sustainable City, which has become an international showcase for sustainable living, work, education, and enjoyment [42]. The city has accepted the concept that everything, including us, is interconnected with the environment. The following illustrates this concept:

- The city is surrounded by thousands of trees, which provide superior air quality and natural ventilation. Nonetheless, it serves as a vital natural habitat for birds and reptiles [42].

- Residents can cultivate their veggies and herbs on the central urban farm. There are 11 biodomes distributed across the city. As a result, the residents' carbon footprint has decreased by eliminating the need for transportation and storage [42]. A gardening campaign encourages residents to plant their organic food on their balconies [43].
- A Sustainable Engineering and Research Institute, a training center, and an international "green school" from kindergarten to Grade 12 are comprised of various sustainable activities. The courses will support the Sustainable City's progressive sustainable model and serve to build a new generation of compassionate problem solvers [43].
- Environmental festivities and seminars are held throughout the city.
- The city has a diverse ecosystem with animals, birds, honeybees, and a wide range of plants, allowing it to establish a fully functional, environmentally-friendly community [43].

5.2.2. RDGs 2. Energy Management

The Dubai Sustainable City has seen many clean energy activities in parallel with Dubai's Clean Energy Strategy 2050, which aims to provide 75% of Dubai's total power output from clean energy by 2050 [44]. Solar energy is an important source that cities rely on to some extent. Compared with the other classic villas, the villas used 40% less electricity [45]. While solar panels were put on the roofs of villas, electricity imports were lowered by an additional 30% [42]. Solar panels were also installed on shaded car parking bays for internal city use. The city adopts several active design features such as [42]:

- Wind Towers of "barajeel" for reducing ambient air temperature and humidity;
- Exteriors of villas were made of glass to benefit from the natural sunlight and less reliance on light bulbs;
- UV-reflective paint;
- Energy-efficient air conditioning;
- LED lighting;
- Solar water heaters;
- Energy-rated appliances.

Passive design characteristics were also considered throughout the project's design phase, with villas facing north to avoid the sun's heat. The L-shaped houses are separated by narrow, green streets that provide shade. According to Dubai's energy consumption statistics, the city consumed approximately 37.2 terawatt-hours of electricity in 2015 [46]. Only 0.023% of this quantity was consumed by residents of Dubai's Sustainable City. The city not only achieved net-zero energy but also ensured the generation of net-positive energy [43].

5.2.3. RDGs 3. Zero Carbon

Following the successful deployment of various initiatives in Dubai, including smart metering and demand-side management, GHG emissions decreased significantly from 5.1 to 4.1 tons due to:

- Using electric automobiles for internal mobility only [47]. The city is now called a low-carbon community. There are free electric charging stations accessible [42];
- Establishing a car-free zone where no fossil-fuel-powered vehicles are permitted. The distance between the parking area and the farthest villa is approximately 90 m, making it walkable [42];
- Using renewable resources such as wind turbines, solar panels, and solar heaters to minimize greenhouse gas emissions [42].

5.2.4. RDGs 4. Water Management

The city makes use of water-saving equipment and appliances to save as much water as possible. Villa wastewater is processed and recycled into greywater and black water for irrigation and farms. As a result, consumers' reliance on desalinated potable water was reduced, and the DSC villas consumed 40% less potable water than conventional villas. Another water-saving strategy is the utilization of local flora such as date palms and swimming pools that use recycled water from the city's water lakes [48].

5.2.5. RDGs 5. Material and Resources Management

In its facilities, the city uses sustainable, healthy, and safe materials. All materials were allegedly subjected to a life cycle assessment before being used in phase two [42]. Figure 11 shows how containers and wood planks are salvaged and repurposed as outdoor seating.

Figure 11. Reused containers and wood as outdoor seats. Source: Author.

5.2.6. RDGs 6. Zero Waste

The city's goal is to achieve 100% waste sorting at the source [42]. The following strategies have been used:

- Residents are encouraged to separate their trash by placing disposal bins near each cluster, which are divided into five waste streams. It is then recycled and reused at "Tadweer", Dubai's largest materials recovery facility [42].
- As indicated in Figure 12, in 2021, the public will have access to an electronic trash station (EFATE) where all electronic devices will be collected and recycled.
- It is not only restricted to city residents but is also open to the general public. Useful components are reused in the creation of new products, while useless components are safely crushed with no environmental impact. Large electrical equipment can be picked up for free by "EFATE". Residents can have defective products refurbished and repaired for free [42].

Figure 12. Green waste is composted on-site to be available for public landscaping.

5.2.7. RDGs 7. Health and Well-being

Diamond developers have guaranteed that the DSC will meet the needs of residents living in metropolitan Dubai since its announcement; it has claimed to be the "happiest community" and has been recognized by the Dubai Land Department for three years in a row [47]. Residents have access to a variety of amenities to fulfill their various needs. Everyone, even disabled people, has access to cutting-edge healthcare. Residents can enjoy and relax in their free time by using open areas and buffer zones. Cycling and walking pathways and the surrounding greenery enable residents to get their daily exercise and interact with nature. Carbon dioxide is absorbed by vegetation, which improves air quality and, as a result, people's health [43].

Furthermore, the city has considered the safety and security of both adults and children to foster an active and social society. All the mentioned factors can lead to a healthy lifestyle and, as a result, a high quality of life.

5.2.8. RDGs8. Regenerative Economy

A regenerative economy aims to create systems that are both healthy and sustainable. The DSC has made tremendous progress toward this goal. It emphasizes resource efficiency through reuse, regeneration, remanufacturing, and recycling. The fact that 11 biodomes are operating, green waste is composted, and outdoor gardening is available all help to boost the city's economy. There is less dependency on fertilizers, and these facilities help improve local products and, as a result, improve the economic pillar of sustainability [43].

5.2.9. RDGs9. Culture and Community

The goal of Dubai Sustainable City was to create a thriving community that welcomed people of all cultures, backgrounds, and beliefs. A wide range of events is held to show solidarity for people of all races and nations. Residents are also permitted to participate in and organize these activities [47]. Weekend markets, seminars, exhibitions, excursions, film screenings, and music are all part of a year-round program for visitors, families, and residents. Residents are encouraged to participate in outdoor permaculture gardens as a way to contribute to the community [47].

The city's low population density of 6000 people per square kilometer allows for a more family-friendly environment [47,48]. The villas' design is influenced by the old "Bastakyia" district, which is one of Dubai's oldest heritage areas [48]. This displays and enriches UAE culture for all citizens, both locals and visitors. Lulu, Berhi, Hilali, Jabri, and Khalas—each cluster is named after a type of palm date tree (a natural plant) [47].

6. Results and Discussion

The nine RDGs developed by the current study were compared with the UN's SDGs to examine their compliance. The comparison revealed that RDGs not only deliver on all the SDGs but offer a holistic and integrated approach to achieving sustainability. They are characterized by:

- Building a coevolution and balanced connection between human beings and their social systems, the built environment, and nature, as reflected in RDGs 1, 7, 8, 9, 10;
- Shifting from minimizing consumption to producing resources through a closed-loop system, as emphasized in RDGs 2, 3, 4, 5, 6. These significant features of the nine RDGs tackle the shortcomings of the traditional approach to sustainability and align with the accelerated rates of ecosystem degradation.

The analysis of the two case studies against the nine RDGs, as summarized in Table 3, revealed that two cases succeeded in applying the nine RDGs by various strategies and techniques within each case; the SEKEM case represented the village scale, which depends mainly on biodynamic agriculture and human resource development for achieving community development through adopting an integrated and holistic approach. Dubai Sustainable City represents the city scale, a residential project that depends mainly on advanced technologies to fulfill the sustainable development demands. The two case studies introduced a successful model that could inspire architects and planners to practice regenerative development and design in the future. The results further proved the practicability of implementing RDGs at different scales of the built environment and in different contexts. The other potentials of nine RDGs derived from the analysis of two case studies were:

- Optimizing the positive impact on the ecosystem. Considering the social, cultural, and ecological dimensions;
- Optimizing the role of people as partners in development;

- Creating more equitable communities;
- Offering a conscious and creative design process founded on a holistic consideration of place;
- Increasing flexibility and adaptability in the built environment.

Table 3. A summarized analysis of the two case studies against RDGs application.

RDGs	SDGs	SEKEM Village Evidence, Methods, Techniques	Dubai Sustainable City Evidence, Methods, Techniques
RDGs 1. Integration of place, nature, and ecosystem	SDGs 1 SDGs 16	Adopting an integrated approach by combining economy, society, culture, and ecology	Incorporating the pillars of sustainability; environment, society, and economy
RDGs 2. Energy management	SDG 7 SDG 13	Increasing Renewable energy share by: Establishing a multi-generation solar power plant Establishing concentrated Photovoltaic Thermal (CPVT) implementing the 'Greening the Desert' project with renewable energy and developing biodiesel fuel	Increasing Renewable energy share by: Using solar panels on villas' roofs and shaded car parking Adopting passive and active design strategies Energy-rated appliances LED lighting Solar water heaters
RDGs 3. Zero carbon	SDG 13	Zero-carbon neutral community by: Establishing a composting facility that reduces carbon emissions Reliance on renewable energy	Significant reduction f GHG emissions by: Electric cars and a car-free neighborhood Reliance on renewable resources
RDGs 4. Water management	SDG14	Using aquaponics in organic food production Developing a wastewater management system Applying low-cost techniques for water recovery Recycling and reusing 100% of wastewater	Using water-efficient devices Native plants Recycling and reusing wastewater for irrigation and other internal purposes
RDGs 5. Material and resources management	SDG12	Producing healthy organic and biodynamic products Recycling and reusing all organic waste on-site	Applying life cycle assessment to materials. Reusing wood planks and steel containers as seats for public Resource efficiency in consumption and production
RDGs 6. Zero waste	SDG 3 SDG 12	Applying proper waste management through: The waste is fully monitored, sorted, and recycled All organic waste is recycled into compost Pharmacy is researching its waste production and has methods to deal with it Reusing waste in the fine arts Better waste collection with economic incentives Implementing zero-waste research	Setting up a waste disposal management Reusing and recycling waste. Establishment of an electronic waste station (EFATE) for recycling defective parts cleanly
RDGs 7. Health and well-being	SDG2 SDG 3	Protecting human health by adopting organic and biodynamic agriculture and producing healthy foods Offering comprehensive healthcare and awareness services Zero carbon neutral Recycling and reusing all its waste-reducing GHG emissions	Adopting the target of the happiest community Improving the mental health of residents through: Open spaces buffer zones with the urban landscape Cycling and walking trails Cutting-edge healthcare service Safety and security systems reducing GHG emissions

Table 3. *Cont.*

RDGs	SDGs	SEKEM Village	Dubai Sustainable City
		Evidence, Methods, Techniques	**Evidence, Methods, Techniques**
RDGs 8. Regenerative Economy	SDG 1 SDG 8 SDG12	Supporting local economies through the supply chain Providing employment opportunities for the local community Providing fair prices to the farmers Offering training on biodynamic agriculture Adopting a circular economy model	Biodomes and composted use reduce reliance on external resources and improve the local economy. Adopting circular economy Resource efficiency in consumption and production
RDGs 9. Culture and community	SDG 4 SDG 5 SDG10 SDG11 SDG16	Focusing on human development and raising cultural awareness through establishing educational institutions Adopting social initiatives Enhancing employee engagement Strengthen the value of equality and cultural diversity	Supporting cultural diversity through public events Promoting community participation Strengthen the societal relationships Conserving the cultural identity and heritage

7. Conclusions

The paper argues that sustainability has become insufficient for addressing the emerging global challenge. This shortcoming resulted from an imbalance between reducing the undesirable impact of human activities and the accelerating rates of ecosystem degradation. Furthermore, it separates human beings from their natural context. Regenerative development has become an evolutionary concept of sustainability that intends to resolve and complement how human beings and their social systems integrate with nature. The research introduced a deep understanding of regenerative development and design, its motivations, definitions, and potential for deeply sustainable development. Based on a review of different principles of regenerative development, the study developed nine goals for implementing regenerative development and design and examined their compliance with the SDGs as well as integrating human and ecological systems with the built environment to tackle the shortcomings of the conventional approach to sustainability. The study investigated and confirmed the applicability of the nine RDGs regardless of the built-environment scale, region, or context. The differences are expected to appear in the adopted solutions and design techniques in each case. Therefore, the study recommends the following:

- Conducting further research to develop an assessment tool to evaluate future built environments for the practical application of the nine RDGs in investigating future communities within the Sustainable Development Goals;
- Building an assessment tool for examining urban development and building design to fulfill the SDGs;
- Conducting case studies at different urban scales and different regions to create a range of methods and techniques for applying and practicing regenerative development;
- Promoting educational programs and courses on regenerative development and design among students, architects, planners, and stakeholders.

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Appendix A

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
Ecologic Life								
5	Share of net revenue of potentially organically certifiable products	%	Holding	59 %	46 %	44 %	47 %	
8	Total number of bee hives	no.		29	50	80	48	GRI 304-1
5	Number of dairy cows per 10 hectare of cultivated land	no.	Company	5	6	5	3	GRI 304-1
5	Total number of dairy cows	no.	Company	129	135	121	96	GRI 304-1
5	Total amount of compost used	t	Company	3 821	6 026	3 343	7 777	
5	Average amount of compost per hectare (SEKEM owned land)	t/ha	Agriculture	19	28	11	22	
5	Total cultivated area (SEKEM + supplying farmers)	ha	EBDA	1 956	1 882	1 648	1 839	
5	Total cultivated area from SEKEM farms	ha	Agriculture	206	218	293	351	
5	Total cultivated area from supplying farmers	ha	EBDA	1 750	1 664	1 355	1 839	
5	Share of cultivated area from SEKEM farms from total cultivated area	%	Agriculture	10.5%	11.6%	17.8%	16.0%	
8	Share of organic matter in farm soils (10 - 0cm)	%	Agriculture	0.7 %	0.8%	0.7%	0.8 %	GRI 304-2
8	Share of organic matter in farm soils (35 - 0cm)	%	Agriculture	0.3 %	0.4%	0.4%	0.4%	GRI 304-2

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
8	pH - Value of Farm Soils (1:2.5)	no.	Agriculture	7.8	7.8	7.6	7.9	GRI 304-2
8	Sodium Absorbtion Ratio	%	Agriculture	6.2%	6.7 %	6.2 %	6.3 %	GRI 304-2
8	Number of seed varieties in own seed bank	no.	Agriculture	n.a.	241	257	280	
8	Amount of effective micro-organisms per gram in farm soils	no.	Agriculture	11×10^10	10^10×11	5×10^6	5^10×9	GRI 304-2
6	Total amount of water usage for agricultural use on SEKEM farms	m3	Agriculture	3,295,027	4,053,245	4,012,668	4,510,343	GRI 303-5
6	Total amount of water usage for agricultural use on SEKEM farms from fossile water source	m3	Agriculture	884755	2,029,890	2,723,687	3,462,903	GRI 303-3
6	Share of water usage for agricultural use on SEKEM farms from fossile water source	%	Agriculture	27%	50%	68%	77%	GRI 303-3
6	Share of waste water recycled and reused for tree irrigation	%	Holding	100%	%100	100%	%100	GRI 303-1
7	Total amount of gasoline consumption	L	Holding	685,250	722,837	710,276	600,851	GRI 302-1
7	Total amount of gasoline consumption for vehicles	L	Holding	369,805	341,192	328,492	405,682	GRI 302-1
7	Total amount of gasoline consumption for power generation	L	Holding	315,445	381,645	381,784	195,169	GRI 302-1
7	Relative amount of gasoline consumption per 1000 EGP sales	L /1000 EGP	Holding	1.6	1.5	1.2	1.0	GRI 302-4
7	Total electricity consumption (grid, diesel and renewables)	MWh	Holding	7 194	6 878	6 595	6 938	GRI 302-1

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
7	Total electricity consumption from grid	MWh	Holding	3.739	2 738	3 348	3 356	GRI 302-1
7	Total electricity consumption from renewable sources	MWh	Holding	301	324	355	1 630	GRI 302-1
7	Total electricity consumption from diesel generator	MWh	Holding	3 154	3 816	2 893	1 952	GRI 302-1
7	Share of electricity consumption from renewable sources	%	Holding	4%	5%	5%	24%	GRI 302-1
7	Relative amount of electricity consumption (grid, diesel and renewables) per million EGP net sales	KWh / 1000 EGP	Holding	17.2	13.9	12.8	11.1	GRI 302-4
9	Total amount of corporate emissions (scope 3+2+1)	tCO2e	Holding	3.934	4 112	4 174	3 704	GRI 305-1
9	Growth of total emissions caused (scope 3+2 + 1)	%	Holding	-21%	5 %	2%	-10 %	GRI 305-1
9	Total amount of emissions scope 1	tCO2e	Holding	1 834	1.927	1 895	1 604	GRI 305-1
9	Total amount of emissions scope 2	tCO2e	Holding	1 694	1 763	1 904	1 678	GRI 305-1
9	Total amount of emissions scope 3	tCO2e	Holding	406	422	375	422	GRI 305-1
9	Relative amount of emissions per thousand EGP sales	kgCO2e / 1000 EGP	Holding	9.4	8.4	7.9	6.0	GRI 305-2
9	CO2 sequestration from soil	tCO2	Agriculture	991	864	5,000	2.569	
9	CO2 sequestration from trees	tCO2	Agriculture	3.362	4 667	1.158	6 988	

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
9	CO2 sequestration from Compost		Agriculture	N/A	N/A	N/A	5.142	
9	Total sequestered CO2	tCO2e	Agriculture	4 353	5.531	6 158	14,699	
9	Total of sequastered emissions sold	tCO2e	Holding	n.a.	1 365	1.709	11,243	
9	Total number of trees	no.	Company	132,000	140,000	150,000	209,645	GRI 304-1
9	Newly planted trees in 2020	no.	Company	7 000	10,000	10,000	59,645	GRI 304-1
10	Total weight of waste	t	Company	383	449	292	271	GRI 306-3
10	Total weight of plastic waste	t	Company	20	32	25	18	GRI 306-3
10	Total weight of paper & carton waste	t	Company	36	41	30	37	GRI 306-3
10	Total weight of glass waste	t	Company	4	14	12	18	GRI 306-3
10	Total weight of organic waste	t	Company	301	330	192	167	GRI 306-3
10	Total weight of hazardous waste	t	Company	0	0	0	0	GRI 306-3
10	Total weight of other waste	t	Company	23	32	33	31	GRI 306-3
10	Growth of total waste	%	Holding	-49%	17%	-35%	-7 %	GRI 306-3

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
10	Share of non-organic waste recycled	%	Company	68%	73 %	75%	74 %	GRI 306-3
10	Relative amount of waste production per 1000 EGP sales	Kg / 1000 EGP	Company	1.7	0.9	0.6	0.4	GRI 3-306
10	Share of organic waste	%	Company	78%	73 %	66%	62 %	GRI 306-3
10	Total weight of all packaging material input	t	Company	1 672	1 970	2 143	2 177	GRI 301-1
10	Growth of packaging material input	%	Holding	-21.2%	17.9%	8.8%	1.61 %	GRI 301-1
10	Total weight of plastic material input for packaging	t	Company	563	514	565	637	GRI 301-1
10	Total weight of paper & carton material input for packaging	t	Company	852	1 160	1 335	1 341	GRI 301-1
10	Total weight of glass material input for packaging	t	Company	201	222	190	139	GRI 301-1
10	Total weight of organic material input for packaging	t	Company	12	15	15	13	GRI 301-1
10	Total weight of stickers material input for packaging	t	Company	33	23	21	30	GRI 301-1
10	Total weight of metal material input for packaging	t	Company	9	34	11	11	GRI 301-1
10	Total weight of others material input for packaging	t	Company	2	2	5	7	GRI 301-1
10	Share of recycled packaging material input	%	Company	2%	59 %	62%	62 %	GRI 301-2

Figure A1. Ecological life indicators. Source: SEKEM Annual Report 2021.

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
Cultural Life								
1	Number of babies in SEKEM Nursery	no.	SDF	27	26	27	24	
1	Number of children in SEKEM kindergarten	no.	SDF	27	50	40	41	
1	Number of students in SEKEM School	no.	SDF	321	301	292	276	
1	Number of students in SEKEM special education	no.	SDF	27	30	32	27	
1	Number of students in vocational training center	no.	SDF	195	224	234	268	
1	Total man hours of training provided	man-hours	Holding	89,307	85,002	68,529	85,734	GRI 404-1
1	Average hours of training per employee	hrs	Holding	69.45	72.96	58.42	67.56	GRI 404-1
2	Number of students in Heliopolis University	no.	HU	1,294	2,533	2,697	2,186	
3	Number of employee visits at the medical center	no.	SDF	5,591	11,060	11,500	30,805	GRI 403-6
3	Total number of medical center visits	no.	SDF	54,151	35,705	30,933	49,327	GRI 403-6
3	Share of employees with private health insurance	%	Holding	%25	%54	%62	%100	GRI 401-2
3	Total number of work related injuries	no.	Holding	0	1	2	9	GRI 403-2

Figure A2. Cultural life indicators. Source: SEKEM Annual Report 2021.

SVG	Indicator	Unit	Scope	2018	2019	2020	2021	GRI Ref.
Societal Life								
15	Ratio of highest to lowest annual full-time salary	no.	Holding	1:26	1:36	1:36	1:38	GRI 202-1
15	Share of females in senior and middle manager positions	%	Holding	14 %	17 %	15 %	17 %	GRI 405-1
15	Share of females in total workforce (excl. daily workers)	%	Holding	24 %	15 %	23 %	24 %	GRI 405-1
15	Number of Senior Managers	no.	Holding	18	7	7	8	GRI 401-1
15	Number of Middle Managers	no.	Holding	93	92	95	100	GRI 401-1
15	Number of Specialists	no.	Holding	462	365	415	417	GRI 401-1
15	Number of Labourers	no.	Holding	568	613	656	689	GRI 401-1
15	Number of Daily Workers	no.	Holding	163	142	140	118	GRI 401-1
15	Total number of employees (without daily workers)	no.	Holding	1,286	1,077	1,173	1,214	GRI 401-1
5	Share of young employees (below the age of 36)	%	Holding	62 %	60 %	59 %	51%	GRI 405-1
15	Share of employees with disabilities	%	All SEKEM	2%	2%	2%	1 %	GRI 405-1
15	Employee turnover	%	Holding	.n.a	15 %	11 %	12%	GRI 401-1
15	Share of longtime employees in the company (+7)	%	Holding	.n.a	49%	51 %	56%	GRI 401-1
15	Total number of part time workers	no.	All SEKEM	6	6	4	5	GRI 401-1
15	Number of supplying farmers	no.	Holding	287	300	307	669	GRI 401-1
15	Absentee rate	%	Holding	1.6%	0.2 %	0.4 %	0.7%	GRI 401-1

Figure A3. Societal life indicators. Source: SEKEM Annual Report 2021.

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