International Journal of Basic and Applied Sciences, 14 (7) (2025) 485-496

SPC

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
https://doi.org/10.14419/rq1nb759
Research paper

The Role of Energy in Acoustical Breathing Architecture

Alaa Jaafar Hasan *

Department of Interior Design Techniques, College of Applied Arts, Middle Technical University, IRAQ, Baghdad
**Corresponding author E-mail: alaa.Jaafar.2021@mtu.edu.iq.*

Received: September 11, 2025, Accepted: November 7, 2025, Published: November 23, 2025

Abstract

Architecture is continuously evolving over the years. However, when it comes to acoustics, the studies are still limited. Furthermore, constant reliance on modern technology has led to environmental issues, such as noise pollution, and physiological issues, including environmental stress and sensory disconnection. Thus, by employing Qur'anic cosmology, this research suggests an innovative philosophical concept called "Acoustical Breathing Architecture" to interpret sound not solely as vibrations, but also as a dynamic interaction of energy within space. Additionally, the research will discuss previous studies regarding incorporating sustainable structures with sound and energy, using a descriptive–analytical method. The topic will be investigated from three directions: the first is a theoretical perspective to discuss conceptual vocabulary, the second is an Islamic perspective, and the last is a practical perspective on sound-emitting and sound-absorbing applications. It was found that the structures can be classified into two types: the first is a sound-emitting structure that converts environmental energy into interactive soundscapes, and the second is the sound-absorbing structure that mitigates sound and creates tranquility. The research proposes integrating philosophical views with design standards to define architecture as a living, breathing body that reacts to sound. The methodology incorporates modern technologies, including Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI), alongside sustainable materials and renewable energy, thereby offering a new human-centered spatial experience with sustainable and interactive characteristics.

Keywords: *Qur'anic Ontology; Renewable Energy; Sound-Breathing Architecture; Sustainable Design; Sensory Experience.*

1. Introduction

Architecture has undergone continuous evolution over the years, driven by the fast development of technology, particularly in terms of sound, space, and sensory experiences. However, these studies have only focused on Western techno-material concepts. An ontological examination of the metaphysical relationships between spatial experience, sound, and energy is necessary.

Therefore, this paper presents a new philosophical term, "Acoustical Breathing Architecture." Rather than being based on mechanical analogies, it employs a metaphysical and philosophical reading of the Qur'anic worldview, specifically Al-Mulk:7, which distinctly expresses a sonic-spatial event integrating energy, sound, movement, and existential consequence.

The verse depicts the loud "breathing" of Hell as violent inhalation associated with movement, fire, and spatial collapse. Rather than a poetic image, the description is a layered ontological construction where sound is created through energy and movement, embedded in space and time.

Using the same concept, space and sound in architecture are reinterpreted as "breathing entities" that can absorb, convert, or emit energy via interactive acoustical design, and they are not viewed as static phenomena.

Both architectural and acoustic literature studies are lacking regarding the concept of "Acoustical Breathing Architecture," making the term and its underlying framework previously unestablished. Therefore, this paper will conduct a systematic review using acoustic theory, design case studies, and glossary sources. The aim is to present this term from three different perspectives: a contemporary sustainable design theory, a philosophical synthesis, and an epistemological contribution rooted in Islamic cosmology.

2. The First Section: The Cognitive Framework

This section will address the general concepts of the research, which are represented by energy, its forms and sources, in addition to addressing the concepts of breathing and breathing buildings, arriving at the operational definition of acoustically breathing architecture.

2.1. Energy

- Scientific Definition: Energy, as stated in the law of conservation of energy, is a constant quantity that cannot be created or destroyed; rather, it transforms from one form to another. [1]

- Physical Definition: In certain physical theories, energy is regarded as the fundamental essence of everything in the universe, serving as the foundation for movement and the transfer of matter from one location to another. Many forms of energy are intrinsically linked to motion, such as the generation of electrical energy, which relies on the movement of electrons. [2]
- Social Definition: When it comes to social concepts, energy is described as the capability to accomplish objectives in a preferred fashion by the influence of an individual/group over others [3]. Energy is the foundation for different entities, which convert from one form to another depending on the required motion.

2.1.1. Forms of energy

The continuous progress of civilization can be attributed to energy due to its crucial role in the development of technology in various fields, making it the foundation of our everyday lives. Energy can be divided into two types: the first one is the potential energy, which is associated with stored force, and the second is the kinetic energy, which is associated with motion [4 - 6].
Sound energy will be the main discussion of this research. When a force causes vibrations, it leads to longitudinal waves traveling through a medium, thus causing sound. When compared to other types of energy, sound has less magnitude. Nevertheless, it converts mechanical inputs into acoustic frequencies, making it a direct manifestation of energy in motion. [7], [8].
The dynamic interaction between potential energy and kinetic energy results in the creation of sound, both as an expression and a consequence of the conversion of energy. The research will focus on discussing this pattern, where the architecture is a breathing system that uses sound to interact with both internal and environmental energy.

2.1.2. Energy sources

The discovery and utilization of energy sources were one of the primary causes of human civilization's prosperity. [9] [10]. They can be categorized into:
Conventional (Non-renewable) energy: As the name suggests, this energy does not replenish itself after a specific period, such as oil, natural gas, and coal. It has been humanity's primary source of energy for centuries, and at the same time, it has been the leading cause of environmental degradation and climate change. [11] [12].
This type of energy constantly replenishes itself, such as wind, solar, hydro, and tidal power. This energy has various advantages: it is sustainable and eco-friendly, and thus it is gradually replacing Conventional energy. [13].
To acoustically shape an interactive/responsive spatial system, the type/nature of energy becomes crucial in investigating the conversion of energy (physical, radiant, or vibrational) into sound within architectural environments. Thus, sound can be interpreted as a spatial expression of energy in motion, an approach that establishes the concept of ‘acoustical breathing architecture.

2.2. Breathing

According to the Oxford definition, breathing is the process of drawing/expelling air into/out of the lungs. Two phenomena are involved in this process: first, breathing, which involves the mechanical movement of air during inhalation/exhalation; second, respiration, which involves chemical reactions that release energy from organic compounds and expel waste products from the body.
The level of control is the primary difference between breathing and respiration; the former is voluntary, and its action mechanism is controlled, whereas the latter is an involuntary process, and its mechanism cannot be consciously controlled, as internal biochemical activities govern it. [14], [15]. In summary, breathing is a mechanical process, while respiration is a chemical process that produces energy. By employing this approach, breathing can be interpreted as both a biological process and a theoretical analogy for spatial systems interacting with energy and sound. Thus, architecture that employs the sound mechanism to interact with energy dynamically is defined as acoustical breathing architecture.

2.2.1. The concept of breathing in the Islamic perspective

The 7th Qur'anic verse in the 67th chapter displays an image that combines movement, energy, heat, and sound into a single spatial event: "When they are thrown into it, they hear from it a (dreadful) inhaling while it boils up" Ibn Kathir and Al-Tabari interpret the word "shahiq" as a terrifying, deep inhalation with a loud sound due to the extreme agitation and boiling of Hellfire as it receives the disbelievers. Rather than being just an illustration of punishment, this verse indicates that the space reacts to what enters it with a violent sonic/energetic conversion, not passively. The act of "throwing" prompts kinetic motion; "inhalation" illustrates an audible dynamic response, and the "boiling" illustrates release of internal energy.
A foundational concept is derived from this Qur’anic illustration to depict the Acoustical Breathing Architecture. Hell is illustrated as a space whose violent breathing is activated by motion and mass. Thus, Acoustical Breathing Architecture is regarded as an active system that absorbs, transforms, and emits energy in a sound form. Therefore, a new philosophical model of architecture is inspired where sound becomes breath, and space becomes alive. This view both agrees with and contradicts other philosophical perspectives. For example, Eastern Taoists regard sound as life energy (qi), whereas Western rationalists regard it as a physical phenomenon with no spiritual significance. [16].
Islamic architectural heritage, on the other hand, views it as a designed spiritual process. Mimar Sinan embedded ceramic jars within the dome of the Süleymaniye Mosque to manage reverberation, creating an alive and immersive sonic space. [17]. That is because rather than just being heard, sound is inhabited, signifying the soul and breath of architecture.

2.2.2. Breathing architecture

Due to progress in building technology and a growing emphasis on human-centered design, the concept of "breathing architecture" has appeared. Using biological metaphors to depict buildings as living systems started in the 20th century, in which buildings accordingly interact with their surroundings, react to stimuli, and adjust their internal conditions [18] [19].
Several evolutions have emerged from this shift, such as innovative materials and intelligent envelopes that control light, temperature, and air to match the occupant's needs. Thus, "breathing cities" has achieved traction at the urban scale to express environments designed for climatic responsiveness and psychological well-being. [20] [21].

A study by ELAttar et al. stated that intelligent envelopes are utilized in breathing buildings to sense/react to environmental changes due to technological systems that improve user comfort, energy exchange, and ventilation, making the envelope a mediating membrane that uses controlled physical flows to enable interaction between interior and exterior conditions. [22].

However, despite optimizing ventilation and environmental performance, they do not address sound as an essential element of architectural respiration. This research interpretation of acoustical breathing architecture is beyond biological analogies to include sonic interaction of buildings (absorb, convert, and emit sound as a form of energy), making the structure a spatially expressive, breathing through acoustics as well as air.

2.3. Sound

Sound can be defined as a form of mechanical energy that utilizes a physical medium (such as air, water, or a solid) to propagate via vibrations. Since its wave motion cannot be transferred without particles, it does not exist in a vacuum. [23] [24]. The definition of sound, according to the Acoustical Society of America (2014), is a longitudinal wave induced by vibrating objects and sensed via the human auditory system. Natural phenomena (thunder and volcanic eruptions) and human-made sources (communication technologies, musical instruments, and engines) are the cause of these vibrations. In summary, it is a chain of energy transformation: It starts with a force that causes motion, then leads to vibrations that produce audible waves (Kuznetcov et al., 2020; Krasnoff, 2021). Thus, it is shown that sound is an active interaction of energy within space rather than a passive one.

In the architectural sense, rather than being a repercussion or annoyance that needs to be mitigated. The current study proposes explaining the sound as a spatial expression medium. That is because the interaction (inhale/exhale) and conversion of energy occur in the architectural envelopes, such as facades and walls, thus the term "acoustical breathing architecture". Therefore, by incorporating acoustic reaction into the spatial structure, it results in a relaxing environment in the emotional and psychological sense.

2.3.1. Psychoacoustics and the impact of acoustic environments on users

Psychoacoustics is a branch of acoustics that specializes in studying the psychological human perception and interpretation of sound. This can be applied in the architectural sense by interpreting sound as a multi-sensory experience that shapes human behavior, mood, and perception.

A subfield of acoustics that analyzes the human psychological response, interpretation, and perception of sound is called psychoacoustics. Rather than being merely a physical phenomenon described by frequency, sound in architectural design is a multi-sensory and emotional experience that forges the mood, perception, and behavior of inhabitants.

Previous research has demonstrated the influence of harmonious natural sounds (such as gentle wind, birdsong, and flowing water) in reducing stress, enhancing social interaction/spatial attachment, and promoting neurological relaxation. Uncontrolled/mechanical noises, on the other hand, result in psychological discomfort, cognitive overload, and irritability. [25] [26].

A study by Blesser & Salter (2007) indicates that, in addition to recognizing sound sources, spatial auditory perception can analyze the symbolic, emotional, and contextual meaning of sound. Furthermore, the study suggests a dimension in which architecture forms sound energy through breathing and speaking. [27].

Such a theory agrees with Acoustical Breathing Architecture, where sound is communicative, dynamic, and breathing force (as a technical constraint). In addition to thermal and visual impact, it has a sonic influence through emotional tone, resonance, and rhythm. Also, the influential performance of Acoustic Design is:

- Mesmerizing sounds can promote longer stays and cultivate a sense of place in public spaces, and enhance social bonds [28].
- Combining natural sounds in therapeutic spaces can enhance patients' mental well-being, support their emotional healing, and reduce their anxiety [29].
- Managing sounds in working environments enhances employee focus, satisfaction, and productivity, while also reducing mental fatigue [30].

2.4. Ontological foundations of acoustical breathing architecture

Most of the acoustic phenomena in buildings (noise control and sound design) were investigated in the architectural approach. However, there is still a gap regarding the ontological/metaphysical dimensions of sound as “breath” within space.

Qur’anic views were used in a philosophical approach, especially verse 7 of chapter 67: “When they are thrown into it, they hear from it a (dreadful) inhaling while it boils up”, which illustrates sound as a reaction to spatial movement and heat (energy), and Hell (Space) as a breathing, sonic entity. Thus conveying interconnection between sound, movement, energy, and spatial tension. This interpretation portrays architecture as an active, breathing, sonic entity that responds to the rhythmic patterns of natural/human energy.

Unfortunately, rather than philosophical, the previous studies' approach to "breathing" is merely a mechanical one (regarding ventilation or bio-inspired envelopes) [18], [31]Furthermore, aesthetic experience, clarity, and sound insulation were used to describe "architectural acoustics" without including the "breathing" term. [32]Additionally, a comprehensive literature review has established that the term "Acoustical Breathing Architecture" is not found in academic studies regarding established architectural theory or a subcategory of sound architecture.

Therefore, inspired by Qur'anic cosmology, this research aims to introduce the term as an epistemological proposition that redefines architectural space as an energy/sound interface, and the study consists of two modes:

- Sound-Emitting Breathing Architecture: converting the energy of kinetic/ environmental motion into expressive soundscapes;
- Sound-Absorbing Breathing Architecture: Calming/neutralizing disruptive energy into acoustic comfort via space.

Thus, examining case studies and real-world applications of acoustically breathing environments can be applied by using the suggested philosophical framework, which connects design methodology and metaphysical perception. The dynamic exchange between sound, matter, and energy within architectural systems is the definition of breathing.

3. The Second Section: Theoretical Framework

Up until now, the "breathing" concept has not been inspected in the architecture field. Therefore, to identify critical aspects of acoustical breathing architecture and filter studies that integrate the "breathing" concept with sound, this section will discuss previous studies to extract crucial observations from related fields regarding the suggested approach.

3.1 (Liao, 2023) assessing sustainable impacts of green energy projects for the development of renewable energy technologies

The study conducted by Liao in 2023 has established that relying on natural resources (such as wind and solar) as a source of energy has reduced dependence on fossil fuels. However, it has faced challenges regarding sound comfort, which were mitigated using dampers and sound walls. Nevertheless, the study has not considered interpreting sound as an active/expressive architectural dimension [33].

3.2. (Masood, 2018) sustainable energy in the concept of kinetic architecture

Another study by Masood in 2018 examined the potential of harnessing wind to generate clean energy in kinetic architecture, aiming to reduce reliance on non-green resources. The study also highlighted the capability of sustainable materials in enhancing sound comfort and reducing noise. However, considering sound as part of a breathing architectural system was not inspected.[34].

3.3. (Rafaely et al., 2022) exploring spatial sound in architecture - a symphony of design and acoustics

The potential for producing immersive auditory experiences that dynamically react to environmental stimuli and human movement was the focus of a study conducted by Rafaely et al. in 2022, which examined the ability of architects' multi-sensory environments to enhance emotional resonance and spatial perception. Furthermore, employing VR and AR before construction to obtain an accurate simulation was also considered. However, the study has focused on the technical angle regarding the sound of architecture and ignored the philosophical and breathing one. [35].

3.4. (Cucharero moya et al., 2022) Acoustic solutions made from natural fibers can reduce buildings' carbon footprints

This study aimed to investigate the influence of sustainable materials, such as wood, on enhancing sound comfort (indoor sound quality and sound absorption) and reducing carbon emissions compared to traditional materials. [36]. Although the study has demonstrated the incorporation of sustainability with acoustic, it has not considered the philosophical interpretation and has focused on the material's performance.

3.5 (Roy & Sander, 2008) the sound of sustainability: acoustics in high-performance design

The research conducted by Roy & Snader in 2008 has indicated a disparity regarding eco-friendly building design, pointing out that the sustainability of buildings is given priority while their sound comfort is neglected. [37].
Therefore, it is important to consider both aspects when designing green buildings to achieve the optimum outcome.

3.6. (Schütz, 2017) The acoustic dimension of landscape architecture

Investigating the sound dimension in architecture by integrating natural noises such as wind and rain was the aim of the research conducted by Schütz in 2017 [38].
In order to reduce noise, various methods have been suggested, such as creating quiet zones, using absorptive materials, installing barriers, and employing vegetation. Despite displaying the capability of acoustically sustainable landscapes, the study has only acknowledged the importance of environmental management and neglected the breathing aspect.

3.7. (Fowler, 2013) soundscape as a design strategy for landscape architectural praxis

Utilizing design techniques such as soundscapes to optimize urban life quality, as was the purpose of this study conducted in 2013 by Fowler [39]. Three main directions were the focus of the study: the first is integrating natural sounds, such as wind, water, and birds; the second is utilizing green energy, including solar, wind, and hydropower. Moreover, the third is the use of noise-lowering methods. The study suggested employing sound-comfort techniques such as dampers and sound walls in green energy sites, including wind farms and solar stations, in order to maintain a positive aesthetic image while mitigating unpleasant noises. Unfortunately, the study has interpreted sound as a functional tool and has neglected the breathing angle.

3.8. (Chen et al., 2024) Acoustic solutions made from natural fibers can reduce buildings' carbon footprints

The aim of the study conducted by Chen et al. in 2024 is to employ natural fibers such as wood and other sustainable materials to optimize sound comfort. [40]. It was shown that not only have the suggested materials lowered unpleasant noises, but also reduced carbon emissions. Although the study has accomplished both acoustic and sustainable criteria, it has only considered the material efficiency and neglected the breathing phenomenon.

4. The Third Section: Theoretical Framework Vocabulary

The key and secondary vocabulary related to Acoustically Breathing Architecture, as identified in the reviewed studies, was extracted, summarized, and reorganized in Table 1 below. Since these terms represent the building blocks, the Acoustically Breathing Architecture concept can be utilized at different scales, including landscape, building, and city.

Key Vocabulary	Secondary Vocabulary			Possible Values		
Types of Acoustically Breathing Architecture Systems	Sound-emitting respiratory systems	Interactive Sound Systems	Environmentally Based Dynamic Energy of Nature (Renewable Resources)	Wind		
				Rain		
				Waves		
				Light		
				Temperature		
		Motion-Based Interactive Sound Systems		Walls		
				Floors		
		Spatial Structure Systems		Audio dimension		
				Audio scene		
				A sensory experience		
	Sound-absorbing respiratory systems	Sound-absorbing systems using vegetation		Green Roofs		
				Green Walls	Moving Green Partitions	
					Living (Green) Walls	
					Vertical Gardens	
		Sound-absorbing systems using modern technologies		Acoustic Dampers	Acoustic Walls	
				Natural (Sustainable) Materials	Natural Fibers	
					Wood	
					Stone	
					Brick	
Level of realization of acoustic breathing systems in architecture	City	Building		exterior		
				interior walls of the building		
		Landscape		Using acoustic barriers and walls	Walls and sound barriers	
					Walls of porous materials	
					Material	Sound absorbing
						Sound reflecting
						Sound dispersing
					Garden and quiet area barriers	
				Designing paths		
				Plants		
				Acoustic techniques	Add sounds (birds-waterfalls-water)	
					Volume control	
					Materials	
				Noise control techniques	Speakers	
					Audio screens	

5. The Fourth Section: Practical Framework

Now that the theoretical approach has been established in the previous sections, this section will discuss the practical approach by applying the extracted vocabulary from Table 1 above to real architectural contexts, demonstrating the potential of Acoustically Breathing Architecture across different scales.

5.1. The sea organ of Zadar: a symphony created by nature and architecture

A combination of innovative design and natural beauty is illustrated in the Sea Organ in Zadar, Croatia (Created by Nikola Bašić), as shown in Figure 1. This architectural/acoustic structure converts the energy of the Adriatic Sea's waves, consequently, presents a unique sensory experience [41] [42].

a) Design and Functionality

- Spanning 230 feet along the coastline, the Sea Organ contains 35 polyethylene pipes with different diameters (70-120 mm) embedded within cement steps.
- The installation has seven parallel musical flights (each 10 meters wide), which create a layered landscape by overlapping.
- When the waves strike the steps, the water pushes the air through the piper, reaching the holes on the display surface and creating sound vibrations with frequencies ranging from 100 to 800 Hz.
- Because of the different lengths and diameters of the pipes and the waves' irregular motion, various musical tones are generated.

b) Natural Integration and Appeal

By demonstrating both sustainability and harmony, the Sea Organ acts through the natural forces of waves and air, displaying the interaction between design and nature, and serving as both a functional seawall and a cultural spot.

c) A Popular Destination

The Sea Organ produces soothing melodies (Especially during sunset), consequently, enhancing the natural atmosphere, and making it a famous attraction spot for relaxation throughout the year, both locally and internationally.

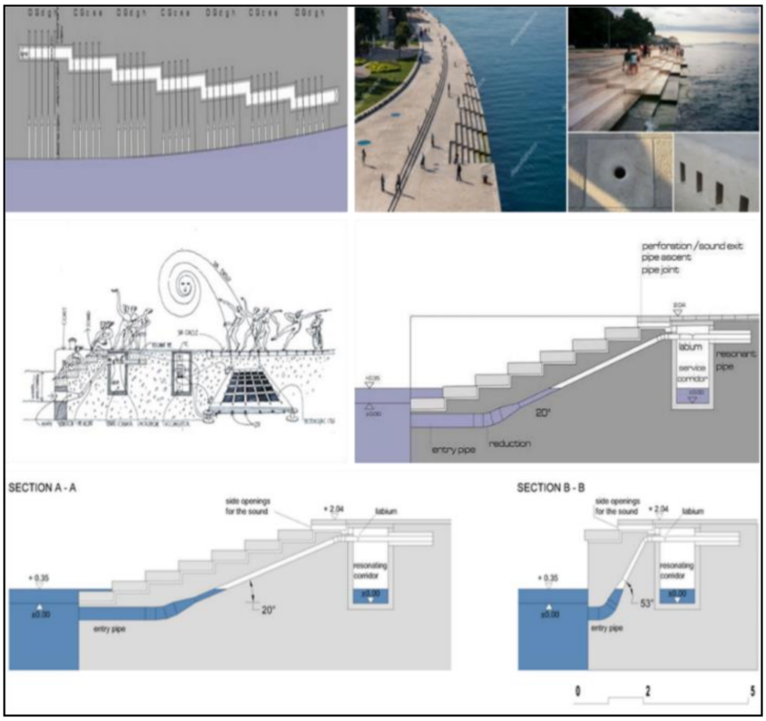

Fig. 1: Architectural and Acoustic Design of the Sea Organ in Zadar, illustrating the interaction of wave motion and built structure to produce natural sound. [43].

The Sea Organ's air holes are strategically placed along the top row of its steps, located in the central aisle. This facilitates the air inhalation process, converting it into musical rhythms. In other words, the kinetic energy of flowing water pushes air through the pipes, generating a unique "sound breathing" effect. Three design methods are required to achieve this process:

- Hydrodynamic Manipulation: Due to the different dimensions/heights of the steps, directing water flow is easy, thereby providing consistent air propulsion via the structures' pipes, enhancing their function.
- Polyethylene Pipe Systems: the strategically placed pipes control air/water movement to create relaxing rhythms.
- Spatial Structures: The architectural design improves the acoustic performance, creating a unique experience.

5.2. Melody road: a novel approach to enhancing driving safety and experience

Improving drivers' awareness to reduce accidents is the main purpose of establishing Melody Road in Japan in 2005 [44]. The project addresses all challenges, such as drowsiness, inattention, and speeding, thus lowering the rate of traffic accidents by approximately 70% (see Figure 2).

The two main advantages of this installation are reducing the dependence on personal audio devices while presenting a unique acoustic atmosphere. For example, speeding around 40-50 km per hr. generates musical tones toward the vehicle to maintain the driver's attention. Furthermore, both the sloop and grooves of the road play a role in creating vibrational sounds, depending on the shape, size, and spacing of the groove. [45] [46]. Closer groves and wider groves produce higher-pitched and lower-pitched tones, respectively, and flat sections are also included to present a continuous rhythm. [47]. Finally, the generated rhythms create a unique sensory atmosphere for the drivers. In summary, utilizing the various shapes of grooves, the road can transform kinetic energy into sound energy, making it an acoustic breathing architecture that displays a unique engineering that combines practicality with innovation.

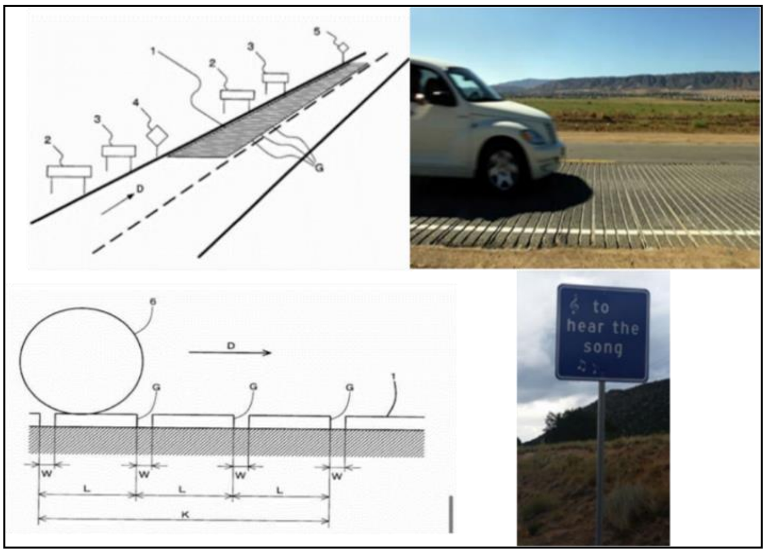

Fig. 2: Transformation of Kinetic Energy to Musical Sound through Engineered Grooves [48].

5.3. Musical rainwater design in Germany

What makes Musical Rainwater a unique urban outlook is that it converts rainy days into a rhythmic experience, as shown in Figure 3. This sensational installation in Dresden, Germany, has been realized due to the efforts of André Tempel, Annette Paul, and Christoph Roßner [49] [50]. The conversion mechanism starts working when rainwater flows in the drainpipes and interacts with the sculptural pipes, creating harmonious tones. In addition, the drainpipes direct water into the rain garden due to their vertical and horizontal arrangement. Thus lowering the risk of flooding and providing both ecological and acoustic benefits. [51].
In conclusion, utilizing rainwater collection systems not only preserves building facades but also supports the irrigation of plants, displaying both an eco-friendly and sustainable building.

Fig. 3: Musical Rainwater Facade in Dresden [52].

5.4. Interactive soundscapes: harnessing wind and water for a sensory experience

This installation is located in England and was designed in 2006 by Mike Tingin. It is shaped like a tree, which fits with the eco-friendly function of transforming natural energy from wind and water into harmonious sounds using sound-producing mechanics (see Figure 4). Providing both acoustic/scenery experience and a tranquil atmosphere [53].
"Singing Ringing Tree" is a prime example of the natural forces' capability to create immersive spaces, acoustically/visually engaging users, and displaying the potential of integrating natural energy with architectural creativity to create inspiring/ functional environments.

Fig. 4: Wind Sculptures: Kinetic Sound and Aesthetic Form [54].

5.5. Jardins sonores de la Borie: a fusion of nature and sound

An innovative integration of natural architecture and sound art is the Jardins Sonores de La Borie (see Figure 5). Designed by Michel Corajoud in 2004, and located in the La Borie-en-Limousin Foundation. This project is a prime example of the harmonious combination of technology, nature, and art, creating an environment that displays the interaction of natural elements and advanced sound technologies. [55] [57].

This installation is influenced by natural elements (water and wind) combined with sound-producing devices that respond to the fluctuating states of nature and the visitor's movement, resulting in a continuously shifting sensory experience as the acoustic environment adjusts to the natural surroundings' dynamic forces and the people's actions.

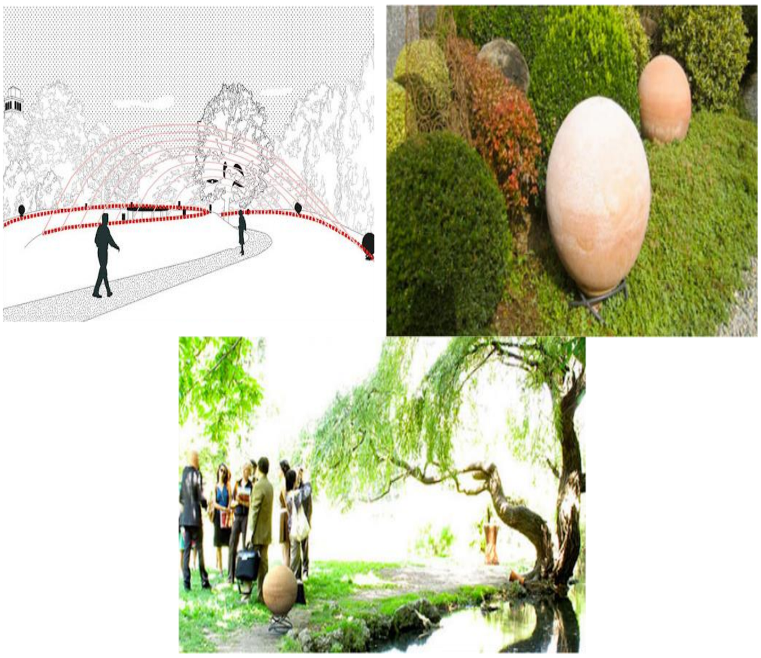

Fig. 5: Interactive Sound Garden at Jardins Sonores de La Borie [58].

5.6. Mobile green wall: the moving hedge as a sustainable indoor design solution

The Moving Hedge is a double-sided green wall designed to manage interior environments acoustically. This can be accomplished due to the dense foliage of the plant and its porous nature, which mitigates sound and reverberation. Also, it acts as a room divider to isolate loud noises. Moreover, it has flexible mobility in order to adapt to any spatial changes, making it distinguishable from other green walls. Furthermore, other investigations have indicated its capacity to manage indoor comfort sound to create a pleasant environment.[59 - 61]. Figure 6 below displays the wall's details. In conclusion, this innovative architecture has presented a practical solution regarding noise pollution challenges in indoor spaces while generating a pleasant experience for people.

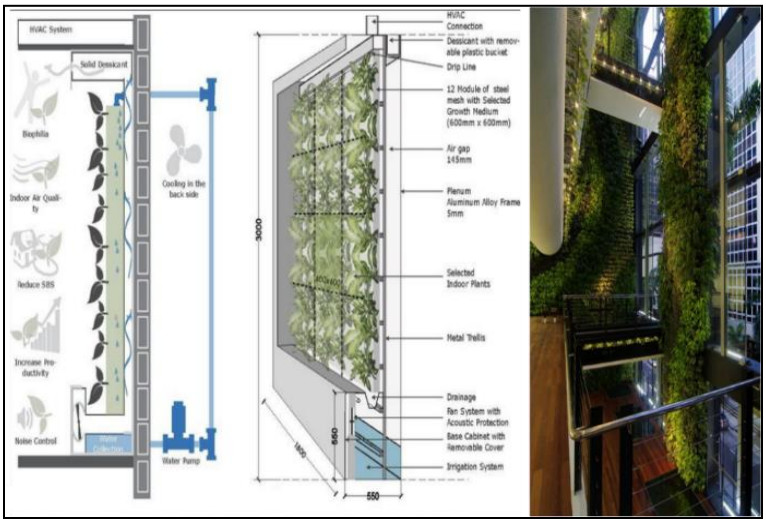

Fig. 6: Design and Schematic of an Integrated Green Wall System for HVAC Enhancement [62].

5.7. Sustainable design with green walls and water features: the 8 Napier, Singapore

The 8 Napier Condominium complex in Singapore demonstrates an intricate utilization of green building design standards. That is because it employs green walls placed in the central courtyard, as well as next to the swimming pool and pond, in order to optimize both the aesthetic and sound-comfort features to create a relaxing experience for residents. [63] [64]. This is done due to the porous structure of the interior wall, which absorbs loud noises, which is a major problem in urban areas [65]. Figure 7 illustrates the details of this structure.

In summary, this condominium complex is another example of employing sound comfort techniques to achieve a sustainable environment and livable conditions for its occupants.

Fig. 7: Harmonious Integration of Nature and Architecture: 8 Napier, Singapore[63].

5.8. The high line: transforming urban infrastructure into a sustainable public oasis

The High Line is an abandoned elevated freight railway that has been transformed into a national park over a period of 6 years (from 2009 to 2014). This has been realized due to the combined efforts of James Corner Field Operations, Piet Oudolf, and Scofidio + Renfro (see Figure 8). The outcome was a combination of natural elements and modern architecture. This renewed park spans around 2.33 km along Manhattan's West Side in New York. [66], [67].

Green spaces and fountains were installed to reduce carbon emissions and absorb noise. Furthermore, motion-sensing devices were applied that manage light and sound according to people's movements to create environmental sustainability and achieve practicality. Highlighting the potential for future renewal projects [68].

Fig. 8: The High Line, New York City: adaptive reuse of urban infrastructure into a sustainable elevated public park integrating green design and smart technologies [69].

Key Vocabulary	Secondary Vocabulary			Possible Values							
				Pro.1	Pro.2	Pro.3	Pro.4	Pro.5	Pro.6	Pro.7	Pro.8
Types of Acoustically Breathing Architecture Systems	Sound-emitting respiratory systems	**Interactive Sound Systems**	**Environmentally Based Dynamic Energy of Nature (Renewable Resources)**	1	0	1	1	1	0	1	0
		Motion-Based Interactive Sound Systems		0	1	0	0	1	0	0	0
		Spatial Structure Systems		1	1	1	1	1	0	1	0
	Sound-absorbing respiratory systems	Sound-absorbing systems using vegetation		0	0	0	0	0	1	1	1
		Sound absorbing systems using modern technologies		0	0	0	0	0	0	0	1
Level of realization of acoustic breathing systems in architecture	city	building		0	0	1	1	0	1	1	0
		landscape		1	1	0	0	1	0	0	1

Fig. 9: Demonstrate The Application of the Main and Secondary of the Theoretical Framework to the Selected Projects: Yes=1, NO=0

6. Conclusions

Inspired by modern sustainable design and Qur'anic cosmology, an innovative philosophical concept called "Acoustical Breathing Architecture" has been proposed by this research to define the interaction between architecture, sound, and energy. It was demonstrated that, perceived solely as a physical vibration or a technical issue, sound can also be interpreted as a form of architectural breathing, a dynamic energy conversion process through inhalation/exhalation.

It was shown from the literature findings that converting kinetic energy from motion, rain, and wind into an acoustic or interactive experience is achieved through sound-emitting systems. While transforming unpleasant sounds into a tranquil/comfort atmosphere is achieved through sound-absorbing systems, such as advanced dampers, sustainable materials, and vegetation. Both systems incorporate natural elements into their architectural design, creating a responsive/multi-sensory environment.

Furthermore, it was illustrated that the potential of acoustical breathing can be amplified by employing AI, AR, and VR to create a customized, interactive, and mesmerizing soundscape, encouraging the addressing of this concept in future projects regarding architectural sound design.

What distinguishes this concept is its capability of producing acoustic/eco-friendly environments, agreeing with the current global standards of relying on renewable and non-polluting resources as the main industrial source. Not to mention, it enriches both human and cultural aspects by integrating the sound system with architecture, evoking identity, emotional resonance, and memory for people, and creating a living entity that reasons with them.

In summary, adapting both Acoustical Breathing Architecture in theoretical and practical approaches results in an integration between human experience, sustainability, and sound. This suggests an innovative idea to enhance cultural life while maintaining an ecological strategy.

7. Future Research Directions

There is room for improvement regarding Acoustical Breathing Architecture, and several promising avenues are required for exploration:

- Psychoacoustic Evaluation of Breathing Spaces

Further research is required to evaluate psychoacoustics and investigate the emotional/cognitive responses of people to sound. The following suggestions are:

- o Assessing attention, relaxation, and stress levels in acoustically breathing places using biometric monitoring and EEG.
- o Measuring mesmerizing emotional reactions using VR Spatial sound simulations.
- o Analyzing conventional acoustically breathing and sound-neutral space using a comparative approach.

Providing valuable data to support architectural decisions and validate this concept will be accomplished through this investigation.

- AI-Driven Adaptive Acoustic Environments

Future angles should be explored regarding the potential of AI in optimizing the interactive relationships between environment, architecture, and people:

- o Dynamically modifying soundscapes using environmental inputs and people's behavior should be done by employing machine learning algorithms.
- o Creating breathing sentient walls that react to people's emotional state and patterns by incorporating AI with IoT sensors.
- o Optimizing neuro-acoustic experience in educational/therapeutic areas using adaptive acoustical feedback systems.

Achieving an effective/energetic transformation of architecture through an intelligent/responsive structure can be accomplished by following this line of inquiry.

- Smart Cities and Acoustic Urbanism

Potential explorations should be considered regarding the incorporation of "acoustical breathing" into smart city systems at the urban scale, where environmental awareness, public health, social interaction, and soundscapes are fostered together. The following suggestions are:

- o Transforming kinetic energy into localized soundscapes using sound-responsive urban infrastructure such as responsive pavements and musical benches.
- o Enhancing comfort levels using real-time environmental data to create sound corridors and quiet zones. Future research may explore how AI algorithms could optimize acoustical breathing patterns based on this live data, incorporating crowd movement, noise levels, and environmental rhythms.
- o Increase awareness regarding urban identity expression and climate using public structures like the Sea Organ or Melody Road to construct new ones.

By merging sustainable urban policy with sensory design and energy awareness, the potential of acoustic urbanism is reinforced.

- Philosophical and Cross-Cultural Expansions

Since a philosophical view can be obtained from the Qur'anic cosmology. Future work can:

- o Compare this framework with Eastern metaphysics (e.g., Taoist qi or Buddhist śabda) and Western phenomenology of sound (e.g., Heidegger, Pallasmaa).
- o Develop a cross-cultural theory of "breathing space" grounded in multi-religious sound traditions (e.g., call to prayer, temple bells, church acoustics).
- o Study how different spiritual environments shape user perception and behavior through sound energy.

- Bio-integrated Materials and Sound Morphology

Material science can play a vital role in enhancing acoustical breathing. Further research may include:

- o Investigating shape-memory materials that alter form (and thus acoustic properties) in real-time.
- o Designing hybrid membranes that function as both living skins and Acoustic organs.

This connects directly to the idea of breathing façades that not only ventilate but speak, resonate, and heal.

Acknowledgment

The author expresses gratitude to the anonymous reviewers for their valuable comments, which greatly contributed to the refinement of the manuscript.

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