Future Cities and Environment

A Review of Domed Cities and Architecture: Past, Present and Future

REVIEW

BLERIM LUTOLLI

ubiquity press

ABSTRACT

The goal of architecture is changing in response to the expanding role of cities, rapid urbanization, and transformation under changing economic, environmental, social, and demographic factors. As cities increased in the early modern era, overcrowding, urbanization, and pollution conditions led reformers to consider the future shape of the cities. One of the most critical topics in contemporary architecture is the subject of the future concepts of living. In most cases, domed cities, as a future concept of living, are rarely considered, and they are used chiefly as "utopian" visions in the discourse of future ways of living. This paper highlights the reviews of domed cities to deepen the understanding of the idea in practice, like its approach in terms of architecture. The main aim of this paper is to provide a broad overview of the need for domed cities in the face of pollution as one of the main concerns in many European cities. As a result, the significance of the reviews of the existing projects is focused on their conceptual quality. This review will pave the way for further studies in terms of future developments in the realm of domed cities. In this paper, the city of Celje, one of the most polluted cities in Slovenia, is taken as a case study for considering the concept of Dome incorporated due to the lack of accessible literature on the topic. This review's primary contribution is to allow architects to explore a broad spectrum of innovation by comparing today's achievable statuses against the possibilities generated by domed cities. As a result of this study, the concept of living under the Dome remains to be developed in theory and practice. The current challenging climatic situation will accelerate the evolution of these concepts, resulting in the formation of new typologies, which are a requirement for humanity.

CORRESPONDING AUTHOR:

Blerim Lutolli, PhD Can.

Bauhaus University Weimar, Faculty of Architecture and Urbanism, DE

blerim.lutolli@uni-weimar.de

KEYWORDS:

Domed Cities; Architecture; Concept of Living; Architecture Pollution

TO CITE THIS ARTICLE:

Lutolli, B. 2022. A Review of Domed Cities and Architecture: Past, Present and Future. *Future Cities and Environment,* 8(1): 9, 1–15. DOI: https://doi.org/10.5334/fce.154

INTRODUCTION

Taking the subject of the 'future concepts of living' is comparable to uncovering one of the most important topics in current architecture. When natural factors demand a reaction, future living concepts are sometimes considered. This is not a straightforward task as designing sustainable living cities for unpredicted and uncertain futures requires a broad range of disciplines (Likitswat 2019). Furthermore, this process requires creativity and imagination to promote resilient learners within the uncertain environment (Sterling, 2010). These new sustainable future models should include incentives for energy saving, reducing consumption and protecting the environment while also increasing levels of users' wellbeing (Riffat et al., 2016).

Hence, if an existential need drives those concepts to evolve further, it is likely that they will lead to the development of new typologies, ideas, and technological solutions that are critical for humanity's livelihood. Domed cities are cities that are contained within a bio-dome. The term "dome" used in this paper is a theoretical approach that consists of the concept of residents living in a vast structure that encloses a large area under a single roof. This structure, which is usually perceived in the shape of a dome, is airtight and pressurized, creating a habitat that can be controlled for air temperature, composition, and quality, typically due to an external atmosphere that is inimical to habitation for one or more reasons. If we think more profoundly, such a dome plays the same role as our houses' outer skin. It creates a better atmosphere inside and provides us with protection.

So, this is not a significant invention; it is simply a third transparent layer of our "shelter." Nevertheless, living in such a dome will give us a better visual connection between indoor living and outdoor green spaces. In addition, since the dome layer will serve as a thermal insulation barrier, there is no further need for thick walls or triple glazing among the inner structures (Adonina, 2020).

From ancient settlements to modern buildings, although the formation and development of cities have mostly been based on sustainable design principles, the industrial revolution led to the rapid growth of towns and uncontrolled rapid urbanization, resulting in unhealthy environments (Terio and Honkanen, 2013). As such, increased urbanization in our cities has simultaneously threatened life on Earth due to extensive energy consumption and environment-polluting behavior, which has made architecture one of the main factors contributing to global warming. Since this unhealthy built environment has increased greenhouse gas emissions, this situation has led to continuous climate change. An essential source of these emissions comes from the generation and use of energy. More innovative passive energy solutions for buildings can be a way of achieving climate goals (Franzén et al., 2019). However, the idea's existence is not as new as it sounds. During the 19th century, there was a universal need to live independently of weather conditions and be protected from large cities' dirt and polluted atmosphere (Wurm, 2007b). This need was architecturally expressed in the idea of covering urban spaces in glass on a large scale (Dinani et al., 2019). Domed cities, found on Earth, a moon, or other planets, have been fixtures of science fiction and futurology since the early 20th century. Meanwhile, today's urban planners are integrating sensor networks, digital information, and cognitive computing technologies to create intelligent transportation systems.

It is unclear exactly when the concept of a domed city first appeared. The Dome was not a research station itself, merely a shell to deflect wind and contain some modest measure of heat. The actual living structures were inside, most of them insulated trailers. The phrase "domed city" had come into use by the 19th century in a different sense, meaning a skyline with dome-topped buildings. The catalog of early science fiction by Mary Griffith in 1836 mentions the fantasy of a future way of living under the title *Three Hundred Years Hence*' (William Delisle, 1881). It describes a future civilization where most of humanity lives in glass-domed cities beneath the sea, allowing the Earth's surface to be used primarily for agriculture. Several examples from the early 20th century are also listed. Those wishing to enjoy nature without shredding their lungs would pay an entrance fee, then frolic for some in a lush natural paradise beneath an immense, airtight transparent canopy. In this catalog of early science fiction, the socialist and the white supremacist fantasy leads to a future civilization, allowing the surface of the earth to be used primarily for agriculture (Bleiler and Bleiler, 1990). Hence, domes became increasingly identified with the idea of the city of tomorrow. The themes were so often found in science fiction. Massive transparent domes, while enormous in scale, were technological, futuristic shapes.

However, domed cities are not always used as utopian concepts; sometimes, they symbolize dystopia, sheltering their residents from environmental contamination, wars, or civic anarchy (Chu, 2018).

The new technological development during the 1960s and 1970s influenced architects to have discussions outside the science fiction confines. This idea gained a new impetus at the beginning of the 21st century and may be explained by an exciting chain of events. At the end of the 1960s, the oil and energy crises were yet to hit; postmodernism was still a marginal heresy practiced by cranks, and, despite a sense of boredom regarding the same old status quo, the tide was yet to turn against state architecture entirely. The overwhelming impression was of accelerating development; humans were on the moon, there was new progress in technologies such as computing, new materials such as plastics were forging ahead, and the desire for social change was bubbling over. There was every reason to think that these movements, in which governments planned and built entire new cities for thousands of people, would continue and progress.

Regarding the current situation, there is more than one reason why domed cities are to be considered a solution to many issues facing users today. They regulate a city's ecosystems, enabling an opportunity to have more moderate temperatures and provide an ambiance without too much rain during autumn or too much snow and ice during the winter. The cities would become far more pedestrian-friendly, cleaner, and secure than the existing ones. This would allow citizens to be more active, which would reduce obesity and eliminate traffic deaths and accidents.

Consequently, citizens could continue their lives undisturbed by whatever weather or other conditions were outside the Dome. By creating a buffer zone inside the Dome, you would avoid heat loss during the winter. So, heating and cooling costs in the summer could be reduced to a great extent.

Beyond the arguments listed above, the fact is that we would not be able to stop climate change and should not stop thinking. To survive, Lovelock (2000) proposes to make climate-controlled cities—domed cities. So this means that global warming, caused by human actions and almost unavoidable, is increasingly becoming a prime threat to humanity. This situation results in polluted, overcrowded, and noisy cities. One of the options is to employ domed cities in these urban areas. If not desired, it might be a single-end solution for humanity shortly.

The rest of this paper highlights the reviews of domed cities to deepen the understanding of the idea in practice, similar in its approach in terms of architecture. This study includes a few small-scale projects undertaken in recent years. These cases emphasize the need for domed cities and present the people's ability to build such structures. Even though these cases, compared to initial ideas, are small in scale, either due to the lack of technological solutions or human willingness, these minor signs show us that living under a dome will happen soon.

DOMED CITIES, UTOPIA OR DYSTOPIA

As early as 1808, Charles Marie Fourier (1772–1837) sought to counter the "ravages of civilization" with his idea of 'Phalansteres,' describing the ideal city as wholly covered in a glass dome (Wurm, 2007a) shown in Figure 1. In 1822, John Claudius Loudon (1783–1843) envisioned placing entire cities under glass roofs to improve living conditions. Particularly cities in the northern regions of the world. The most economical method of creating an agreeable climate will be to cover whole cities with monumental glass roofs (Loudon, 1824).

Figure 1 Charles Marie Fourier, 'Phalansteries' (Wurm, 2007a).

Man turned the notion of the 'Paradise Garden' into the "lost paradise.' The displacement of men into multiple temporary places has made people continually adapt to their living areas. Humankind aims to reverse the position where we were created—the Earthly Paradise. The idea of Paradise was also pursued pragmatically, notably by the Romans, who created artificial climates in heated enclosures (LeCuyer et al., 2008). During the Renaissance, Humanistic preoccupations developed a new version of the ideal world. The imaginary island in St. Thomas More's book Utopia, written in 1516, was the conceptual site of a perfect social and political system (KIBIN, 2020). The concept of Utopia was like the Garden of Eden. A bordered domain would enable harmonious social ties in opposition to harsh conditions elsewhere.

At the same time, the systematic study of nature in the Renaissance produced botanical gardens; the first was in Padua in 1543; it sought to gather the world into a single domain (Toorn, 2017). The first step to inverse this lost paradise was the botanical gardens shielded with glass. This momentously influenced what was later known as "domed cities."

Sir Joseph Paxton (1803–1865) made the Chatsworth gardens one of the grandest in the world. In 1841, he completed the "Great Stove," a vast football-field-sized greenhouse, the largest glass building in the world shown in Figure 2 (Markham, 1950). In his book, "Fact or Fantasy – World of Tomorrow," Neil Ardley (1937–2004) revealed a city beyond the arctic Dome, shown in Figure 3.

In early science fiction pages and futurology texts, domed cities achieved worldwide attention. This led to the idea that making harsh environments perfect for human life is now being studied in architecture.

Beyond science fiction, a concrete project dome is Buckminster Fuller's idea for the dome 3 km wide and 1.6 km high glass hemisphere over Midtown Manhattan, as shown in Figure 4, aimed to overcome weather problems,

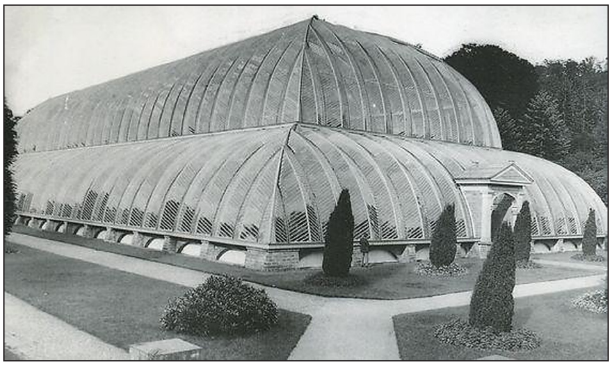


Figure 2 Glazing greenhouse at Chatsworth with ridge-and-furrow (Markhamm 1950).

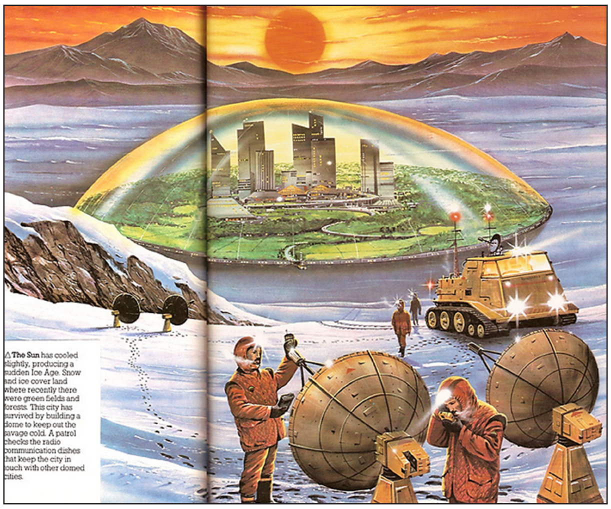


Figure 3 City beyond Arctic Dome, "Fact or Fantasy, World of Tomorrow" (Ardley, 1982).

reduce air pollution, cooling costs in the summer, and heating costs in the winter. Fuller's photomontage of the project portrays the Dome as an artificial bubble enclosing the world's most constructed environment, Manhattan—a representation that continues to capture people's imagination today (Fuller, 1969b). It is hard not to consider the project as a spectacular object. Nevertheless, while this representation emphasized the project's unprecedented scale and striking form, Fuller's written explanations were more pragmatic, discussing construction details and energy savings. They conceived the Dome as a super-envelope within which the city's many processes could be managed and balanced (Keats, 2016). The idea is stunning in its reductivist aim to solve numerous complex problems with a single architectural gesture. Nevertheless, the project raises important considerations as we identify and develop design techniques to solve today's environmental challenges.

It was partly inspired by the fledgling space program, the utopian architecture of the 1960s produced images of floating communities hovering among the clouds. Buckminster Fuller created a concept entitled "Project for Floating Cloud Structures (Fuller, 1962), shown in Figure 5". Fuller's fictitious floating sphere-enclosed cities

Figure 4 Dome Over Manhattan (Fuller, 1969b).

Figure 5 Buckminster Fuller, Cloud Structures (Fuller, 1962).

are given a sense of feasibility through technological explanations that make them possible. In the early 1960s, the visionary architect drew up concepts for spheres that would hover above the planet and accommodate thousands of "passengers."

Fuller, who proposed several domed cities worldwide, went further than his predecessors by suggesting airborne habitats created from giant geodesic spheres, which could have been used to levitate by slightly heating the air above the ambient temperature.

> *"It is obvious that the real wealth of life abroad on our planet is a forward-operating, metabolic, and intelligent regenerating system. Moreover, we have vast income wealth such as solar radiation and moon gravity to implement our success. Therefore, living only on our energy savings by burning up the fossil fuels burning up our earth's atoms is lethally ignorant and utterly irresponsible to our coming generations. We are cosmically bankrupt if we do not comprehend and realize our potential ability to support all life forever."* (FULLER, 1969a).

Through that time, architects began to recommend similar concepts for various locations. One very sublime example was the proposition of a dome over the Arctic. With a 2 km span where 15,000 to 45,000 inhabitants could be accommodated, the Dome was enclosed within a pneumatically sealed envelope, suited to deal with icy climate conditions by creating an adequate living environment (Whitehead, 2021). Only a few architects proposed examples like these. However, more interesting is that communities in different cities were interested in such ideas during that time. One of the magnificent examples was a dome over a small town in Vermont in the United States, known as Winooski. This idea was revealed in 1979 by the eager and creative city designers led by the town's Community Development division (Khosrowjerdi et al., 2021). The plan was designed to fight against the city's harsh climate—nine months of wintry weather and three months of awful skiing. Their suggestion was a dome of an enclosed 880 acres. This would reduce the city's heating expenses by 90 percent. Considering that this was a time when the U.S was suffering from high energy prices, this vision was undoubtedly a tempting idea.

These projects failed because of a lack of scientific explanations and a lack of financial resources. The idea of having a dome over a city did not vanish; it only became ever more critical within the architectural world. This was distinct in parts of the world with harsh climates. The last couple of decades has brought us to a significant appropriate shift. An excellent example is the Amazon Biodome building, recently finished, representing a reverse side to the idea of domed cities.

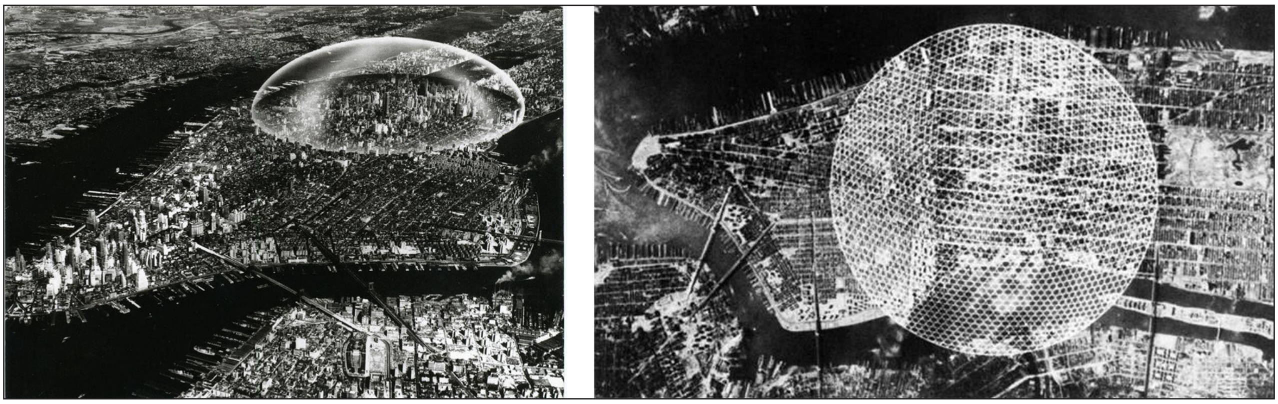
DOME OVER MANHATTAN

One of the first concepts of a real domed city came about in 1960 when engineer Richard Buckminster Fuller and architect Shoji Sadao, proposed a 3 km wide and 1.6 km dome high over Midtown Manhattan shown in Figures 6 and 7. Dome over Manhattan, was one of Fuller's numerous domed visions for sustainable living (Cureton and Dunn, 2014). The plan was for the giant Dome to regulate weather and reduce air pollution to cut cooling costs in the summer and heating costs in the winter, thus enabling citizens to continue with their lives undisturbed by whatever weather or other conditions were going on outside of the Dome.

According to the designers, the Dome's weight would be equal to the air beneath. It would be secured in place by cables because, in a hot climate, it tends to hover. The Dome would have an expanse of approximately 1/84th of the buildings enclosed. As a result, heating and air-conditioning expenses would be dramatically reduced. The whole Dome would be kept at a reasonable temperature, eliminating the need for structures to be heated and cooled separately. However, the In-dome apartment building would have higher rents to deal with the cost of the climate management of the whole Dome. Hatch (1976) further explains that *"Its skin would consist of wire-reinforced, one-way vision, shatterproof glass, mist-plated with aluminum to cut sun glare while admitting light. From the outside, it would look like a great glittering hemispheric mirror, while from the inside, its structural elements would be as invisible as the wires of a screened porch, and it could appear as a translucent film through which the sky, clouds, and stars would appear."*

However, the designers estimated that the cost of snow removal in New York City would compensate for the Dome in 10 years. According to the New York Times, the city paid out $92.3 million yearly to remove snow. Melted snow and rain could be accumulated in gutters and channeled to reservoirs.

Fuller's claim for enclosing Manhattan in a glass bubble reads as rational, reasonable, and even-keeled. Howard Smith's interview from 1971 was recently published in (Fuller, 1972) *"I invented a way of enclosing space with a geodesic dome, which is much stronger and more efficient than other ways. I began to study how big a dome I could build and see whether, if you made them bigger, the economics of it began to be unfavorable, and I found that the bigger they got, the more favorable they were. So, I finally calculated one-two miles in diameter, how much material it would be, the members' size, and how long it would take to get in place. Having calculated, I found it very economical and would be very advantageous. I would like to see what a two-mile-diameter dome would look like about something we are familiar with. Manhattan at Forty-Second Street is*



Figures 6 and 7 Dome over Manhattan, Buckminster Fuller, Manhattan (Fuller, 1969b).

exactly two miles wide, so I said I will get an airbrush and an aerial photograph, and then I can superimpose this two-mile Dome to see what it would look like if I did that. During those great water shortages, we have great thunderstorms in New York, and all the rain just goes down the storm sewers. Beautiful rain, but it just goes down the storm sewers, and no one can consume it. Once you put a big dome-like that up, you have beautiful guttering around, and this all gets channeled off to a holding, to a great reservoir. So, it would be very worthwhile to have cities under geodesic domes. Still, in New York City, if you think about all the different owners of different lands, the controversy about "this in my air rights, I don't want a thing over my thing here," I just do not think it is going to happen with New York City. But it can happen where you start in places where energy is a great problem."

MINNESOTA EXPERIMENTAL CITY (MXC)

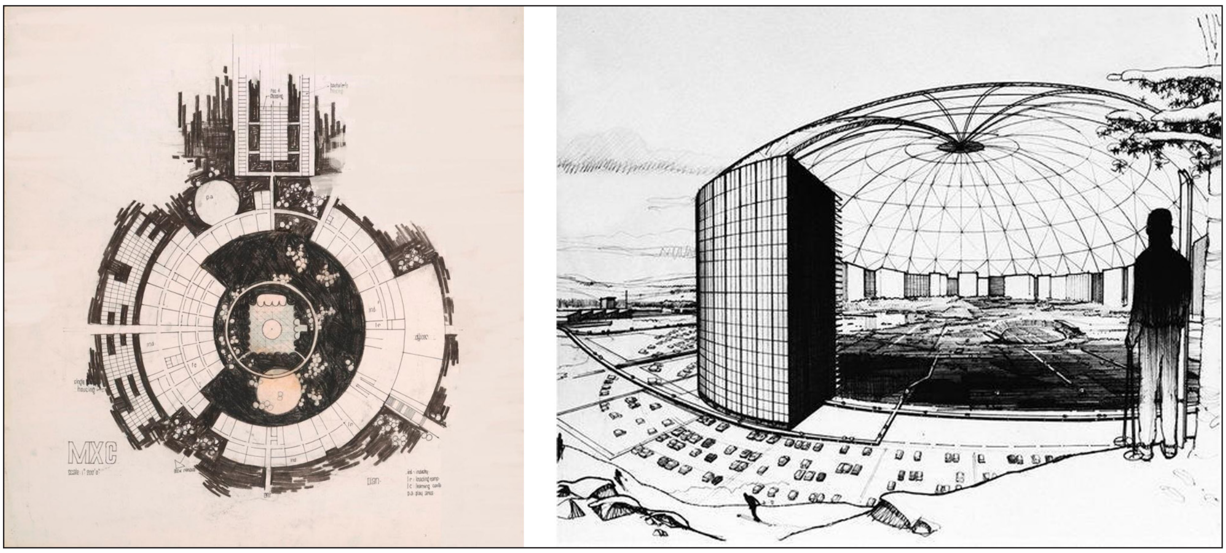
Introduced by Athelstan Spilhaus (McCormack and Phillips-Hungerford, 2019), the Minnesota Experimental City (MXC), as shown in Figures 8 and 9, proposal was launched as a way to provide a living laboratory to model and carry out groundbreaking pollution control techniques in the beginning of 1960s. Proposed in northern Minnesota near Swatara in Aitkin County, its initial goals involved complete material and water recycling, eradicating the internal combustion engine, and enclosing all or part of the city under a geodesic dome. Like many other academics of the era, Spilhaus believed that America confronted two rising catastrophes: the continuous depopulation of conventional metropolitan centers and the exponential increase of waste and pollution. The completion year was estimated to be 1984 with a total cost of the project at $10bn (Rose, 2018).

Spilhaus further suggested the Minnesota Experimental City (MXC) as an all-in-one answer to both crises, promoting that the nation accommodates its population growth between 1970 and 2000 in distributed new cities centered on the MXC model (Wildermuth, 2008). In contrast to many of the prototype cities of the time, the MXC was intended for 250,000 people over 60,000 acres, free of the impacts of current cities. It was to be investigational; new things would be studied rather than planned to select from the best of the current practice.

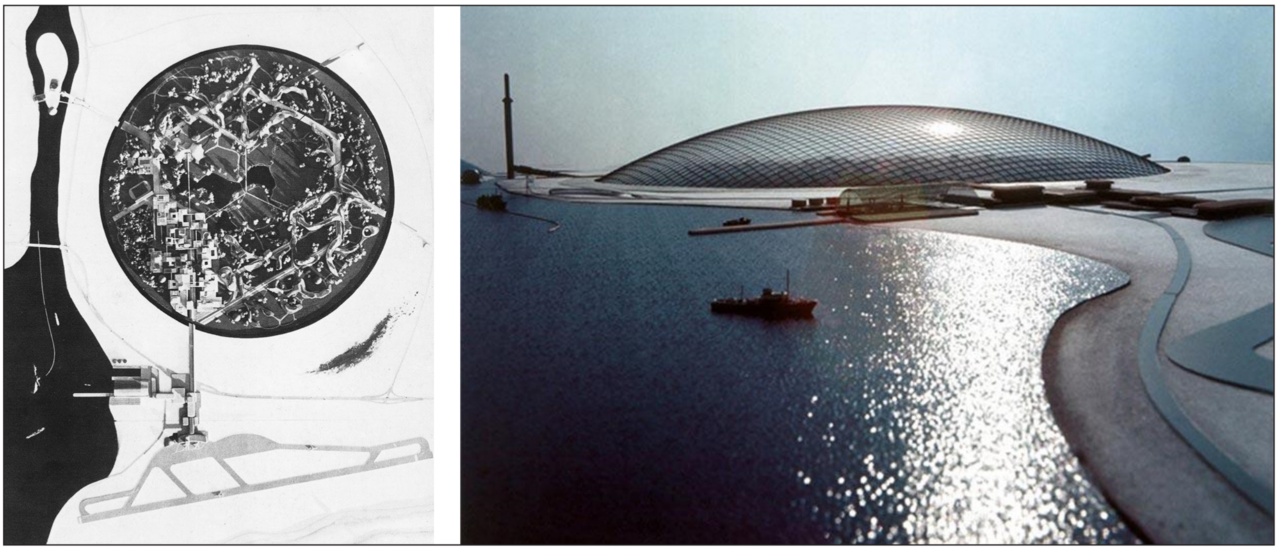
Under the influence of Buckminster Fuller, the strategy called for the MXC to be covered by a geodesic dome which would have offered an energy-efficient way to maintain a comfortable year-round temperature. Waste would have been reused, and food would have been produced under the Dome. There would be no cars inside the Dome. Instead, people would park at the Dome's border and use electric trolleys and transportation methods linking all locations (Wildermuth, 2008). Interesting is the fact that Minnesota Experimental City was seen as attractive by many investors like Boeing and Ford; however, due to the financial crises of the 1970s and the protests among different environmental activists the project failed to be a reality.

THE ARCTIC CITY

A close vision of the Manhattan Dome was suggested by architects Frei Otto, K. Tange, and Ove Arup (Oliva Salinas et al., 2018) at the beginning of the 1970s, as shown in Figures 10 and 11. This idealistic town of 15,000 to 45,000 citizens, enclosed within a pneumatically sealed wrapper, was aimed to deal with icy climate conditions by creating an acceptable climate for living in the Arctic. The design was perceived as a "town," which collected a variety of uses for the program. With a harbor for shipping access and an airport on the outskirts, the manufacturing area would have been located just outside the city, while



Figures 8 and 9 Minnesota experimental city, Conceptual site plan, and Perspective (Wildermuth, 2008).



Figures 10 and 11 The Arctic City –Model, Unbuilt (Oliva Salinas et al., 2018).

the management and entertaining sectors would have been at the center, linked to the housing units through corridors and moving walkways. Cars and pedestrians were interconnected on several different levels. Otto recommended that the city be built in tandem with a nuclear energy station to provide power, heating the town's space and keeping the water perceptually ice-free.

According to the designers, this project proposal was envisioned as a pneumatic dome spanning 2 km and consisted of a double-layered transparent foil held by a steel cable net. Pressurized air would be responsible for the structural support of the Dome. The form of the Dome would thwart snow accumulation, resist severe wind, and provide fresh air and heat ventilation employing nuclear energy.

> *"The first stage was to prepare the site by digging a set of external foundations in a 2km-wide ring. Then a grid of cables, formed from a newly developed high-strength polyester fiber rather than steel, would be laid across the site and fixed together. The double-layered translucent pillows that would create the skin would then be attached before the entire Dome was inflated to a height of 240m at its peak. By not building from steel, the roof could behave as skin rather than a true dome, meaning that it would be less susceptible to wind, snow and changing loads"* (Barthel, 2018).

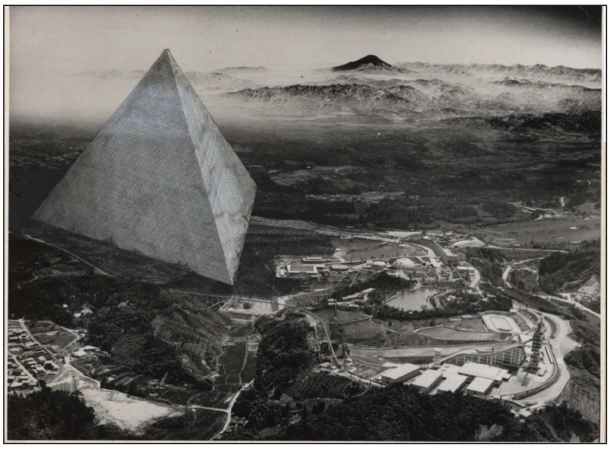


Figure 12 Tetrahedron City in Japan (Huebner, 2021).

Figure 13 Tetrahedron City in San Francisco (Huebner, 2021).

TETRAHEDRON CITY

The spherical shape of the Dome was not the only geometrical form devised for these innovative megastructures. Created by Fuller and Sadao, this translucent pyramid proposal was conceived for the wealthy Japanese financier Matsutaro Shoriki (Huebner, 2021), shown in Figures 12 and 13. Shoriki wanted a solution for Japan's congestion and envisioned boats joined together to make a floating, earthquake-proof structure. Fuller produced a tetrahedron shape, which provides the most surface area with the least volume—a four-sided triangular solid with each edge measuring 3,200 m. This striking metropolitan area was designed to accommodate around one million citizens in 300,000 apartment units and would have included a massive harbor contained by the structure (Pawley, 1990).

Huebner (2021) envisioned this Tetrahedron City as an effective response to two considerable problems of architecture and urban planning: construction expenses and land procurement. The tetrahedral composition with an aluminum octet tether system makes the structure's enormous size viable and cost-effective. *"The whole city can be floated out into the ocean and anchored. The depth of its foundations will go below the turbulence level of the seas so that the floating tetrahedron's land will be, in effect, a floating triangular atoll. Its two-mile-long "boat" foundations will constitute landing strips for jet airplanes. The total structural and mechanical materials involved in the production of several such cities are within feasibility of the already operating metals manufacturing capabilities of any company of the several major industrial nations around the earth. The tetrahedron city may start with a thousand occupants and grow symmetrically to hold millions without changing overall shape though always providing each family with 200 sq. ft. of floor space. Three-quarters of the earth is covered by water. Man is intent on penetrating that world-around ocean waters in every way to work their ocean bottoms, marine life, and chemistry resources. Such ocean passage shortening habitats of ever transient humanity will permit his flying sailing, economic stepping stone travel around the whole earth in many directions"* (Marks and Fuller, 1973).

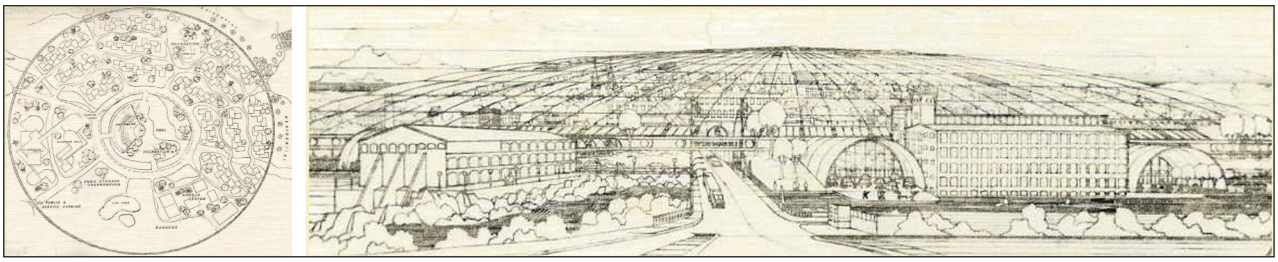
However, after Fuller's Tetrahedron City failed in Japan, the U.S. Department of Housing and Urban Development appointed him to analyze further than the previous concept of Tetrahedron City in the San Francisco Bay, seeking to be the first fully green city (Kronenburg, 2014). After both failed attempts to realize a Tetrahedron City, Fuller developed another concept called "Triton City," which, in fact, was smaller in scale in comparison to the other two pyramid models. Triton City was a model for an anchored floating city of around 100,000 residents positioned seaward and linked with bridges to the mainland. The massive pyramid was envisioned to be multifunctional, providing different options within the structure, harbor, greenery area, etc. His concept gave the flats low management costs and high living levels. He further bolstered his idea by claiming that floating cities pay no rent to proprietors. Several architects have adapted these concepts, and today there are many cities where land is in short supply, such as Singapore, Shanghai, Tokyo, etc., where this model could be accomplished.

WINOOSKI DOME

The concept of the dome over Winooski in Vermont in the United States started with a concept initiated by creative young city planners whom Community Development Director Mark Tigan led. Due to the challenging climate of Vermont, where there are nine months of winter and three months of bad skiing, they suggested enclosing their town in a giant 880-acre dome (Hale, 1979). As a result, its residents spend around $4 million yearly to stay thawed. The idea of constructing a dome over Winooski was shown in 1979, the time when the U.S was experiencing high energy costs. Everything shown in Figures 14 and 15. Advocates argued it was a very sensible response since it could cut the city's heating costs by 90 percent.

Architect John Anderson was put in charge of delivering drawings of the Dome. His vision was not a hemispheric shape but more like the top half of a hamburger bun (Wallace-Wells, 2021). While supporting their idea, he stated, "Air would be passed inside by large fans and warmed or chilled, as required". The Dome would be held up by air pressure just marginally above atmospheric pressure. Entrances and exits would consist of double doors similar to an airlock. The homes inside would require no individual heating or cooling *"you could grow tomatoes all year-round."* It would come down gradually if the Dome were pierced, allowing for sufficient warning.

A short time after the idea was offered, town planner Mark Tigan opted to call the Department of Housing and Urban Development (HUD) in Washington. They loved the idea and urged the city planners to follow it. Professionals around the country make contact with Winooski about the domed city concept. One was R. Buckminster Fuller, who contributed to the International Dome Symposium (Hale, 1979). Fuller commended the city for exploring the idea and encouraged them by saying it was feasible. He then proposed numerous geodesic domes instead of one significant covering. Winooski's Dome aimed to cover the entire town, 800 times that area (Hale, 1979). He emphasized that the biggest question was not keeping the Dome up but holding it down counter to the force of increasing warm air. He proclaimed the engineering "not difficult" and pointed to current structures like large airport terminals in Riyadh, Saudi Arabia. The U.S. Pavilion at Expo Montreal in 1976, 200 feet high and 250 feet in diameter, covering 1.1 acres, was already built by



Figures 14 and 15 Dome over Winooski (Weird Universe, 2022).

Fuller. In one way, he was trying to convince them by contemplating his experience, examples, and concepts concerning the topic.

Besides the issue of financial funding, during that time, not unexpectedly, people raised concerns about the Dome (Peck, 1979). They already had contradictory views about the ideas. The media and society performed an essential role in declining this concept, resulting in the project's decline during Winooski's request for funds by President Carter. Even now, after 40 years, such a concept is still under debate for Winooski. Mark Tigan, now an associate professor at Clark University, claims, "Economically, it is a slam dunk. The biggest issue, he believes, would be the public taking of land via eminent domain to secure the area around the edges." Such issues, Tigan expects, will become more common in the future as environmental sustainability and even survival become economic issues (Tigan, 2005).

DOME OVER SIBERIA

Known as Eco-City 2020, a domed city of around 100,000 citizens was planned to be built in Siberia in one of the giant opencast mine pits in the world, with a diameter of 1.2 km and a depth of 530 m (Duerden, 2010) shown in Figures 16 and 17. Mir-Mine was known as the world's leading and most prolific diamond source, however, it discontinued operations in 2011 after the pit ran dry. This was why this massive hole came to the awareness of this construction company, who began thinking of making plans to convert it into a magnificent living space and investigational city of the future.

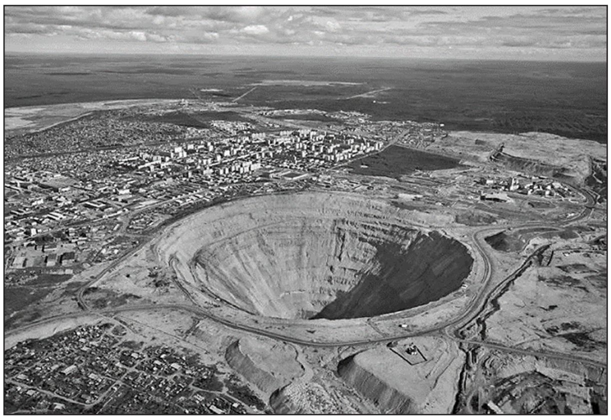


Figure 16 Mir-Mine-Siberia (Duerden 2010).

Figure 17 Dome over Mir Mine- Siberia, Rendering 2010 (Duerden 2010).

"The new city is planned to be divided into three main levels: a vertical farm, forests, residences, and recreational areas. However, one of the most interesting aspects of the proposal is the glass dome that will protect the city and be covered by photovoltaic cells that will harvest enough solar energy for the new development" (Duerden, 2010). The concept involves building a massive glass dome over the pit's entrance, luxury residences bordering the terraced walls and parks, an oxygen-producing greenhouse, and an eco-friendly and space-saving 'vertical farm' in the central area. The Dome and ditch, named 'Eco-City 2020,' would be self-sufficient, ecologically friendly, and comfortable in a cold region like Siberia, supplying houses for up to 100,000 inhabitants (Duerden, 2010). The extreme Siberian sun is the key to the impressive design (Geere, 2018). Light would be guided through the city's central hub into its lower levels, where oxygen-producing trees, farms, and other services would be located. Photovoltaic cells constructed into the Dome would generate all the city's electricity. Inhabitants in the city's upper levels would profit from a more consistent, enjoyable climate, unlike the bitter cold of the Siberian periods. They could appreciate the city's stunning parks and gardens all year. Unfortunately, the proposed future city has stayed just a proposal, and no projects have yet been made to begin building.

ENVIRONMENT BUBBLE – "UN-HOUSE"

The concept of Environmental Bubble comes from Architectural critic, and historian Reyner Banham described in his essay "A Home is not a House" in 1965. His Environment-Bubble proposal consists of a domesticated utopia equipped with modern amenities (Banham, 1965). His manifesto attacks communities built without proper safeguards from cold and warm weather based upon the prevalent use of heating pumps, a general misuse of energy, and the fabrication of "environmental machinery." Based on Banham's Essay, François Dallegret created the "Un-House" illustration, shown in Figure 18. It shows a transparent plastic dome which encloses an air conditioning system (Ponte, 2009). The house is folded down to the baggage size that the itinerant dweller can carry around with them, ready to set up at any site. It featured the latest in environmental controls and electronic entertainment—or what Banham refers to as the junk that keeps the pad swinging (Banham, 1965). Banham devised "Un-house" as a rudimentary hut in which the inventive,

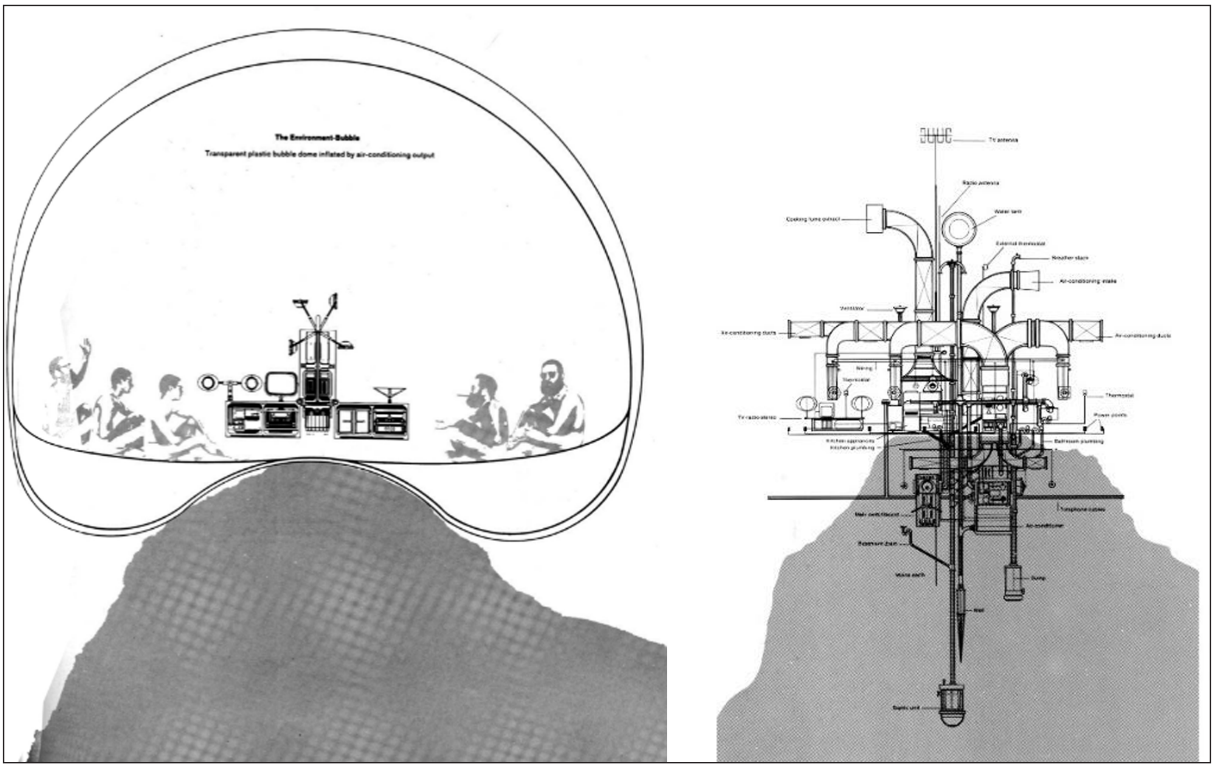


Figure 18 Environment Bubble – "Un-House".

highly automated infrastructure system becomes the core of living space, replacing the fireplace of ancient accommodations. The infrastructure, on a small scale as a transportable standard of living package, guaranteed that the dwellers had everything they needed like heating, cooling, ventilation, telecommunications, and electricity (Wingfield, 2016).

When a house contains such a complex of piping, flues, ducts, wires, lights, inlets, outlets, ovens, sinks, waste disposers, hi-fi reverberators, antennae, tubes, freezers, heaters – when it comprises so many services that the hardware could stand up by itself without any aid from the house, unlike monumental architecture. The 'Environmental Bubble,' enclosed in a transparent inflated plastic dome, is a drastic departure from typical living arrangements. It has the potential to reduce a house's configuration and envelope to a transparent bubble inflated by an air conditioner, creating visible and physical links between home, technology, and nature. Banham (1965) investigated other theorists and experts throughout the twentieth century and suggested a new way of living on the American frontier as an alternative. He states that dwellings in America have been shells to hide and monumentalize the ecological controllers and technologies. Hence, the 'Environment Bubble' is still a brilliant example of how future technologically confrontational proposals might be effectively communicated using layered rhetoric and how nominal environmental adjusters are used in aggregation with an ever-movable power foundation to bring families nearer to nature.

MONTREAL BIOSPHERE

Designed by Buckminster Fuller for Expo Montreal in Quebec, the Montreal Biosphere is a small-scale example of what Fuller had been working on all his life for the Dome cities agenda. This sphere-shaped structure – shown in Figure 19, could be believed as a small-scale effort at his idea for the domed city in Manhattan, which recognized Fuller with a distinctively moral blueprint for his progressive designs. Committed to the environment, the Montreal Biosphere was established to create a livable space using only one-fifth of the resources typically used in traditional architecture. Fuller's aim was to improve human dwellings by making them more efficient and affordable (Noakes, 2021). As an

Figure 19 Biosphere Montreal (Buckminster Fuller in ArchEyes, 2016).

architectural accomplishment, the Biosphere epitomized Fuller's glorification of the promise of technology. Through universal consideration, systemization and mass-production, Fuller saw this project as an illustration of how architects could wield and utilize the instruments of modernization to create new species of hyper-efficient technologies for the good of humankind (Dalvesco, 2017).

The Dome is a symmetrical icosahedron, a 20-sided shape of pentagons scattered in a hexagonal grid. However, the clarity of this form is complicated by the fragmentation of its faces, which are segmented into a sequence of symmetrical triangles with minor alterations that bow the different two-dimensional sections into shells. The enclosed structure of steel and acrylic cells is 76 m in diameter and 62 m high. A complicated system of shades was used to manage its internal temperature. Currently, the Biosphere serves as an environment gallery that offers collaborative activities and exhibitions on the significant environmental issues related to water, climate change, air, eco-technologies, and green development. Being dedicated to exploring the links between society and the environment, its mission is to encourage citizens to take an active role in ecological and environmental issues (Noakes, 2021).

AMAZON BIODOME

One of the best real examples where the theory for the domed cities can be tested in real life is probably the Amazon Biodome. Designed by NBBJ for Amazon in the center of Seattle, the project began in 2012 and was finished in 2018. As showin in Figure 20, the Amazon Biodome is conceived in three bubbles 29 m high and involves approximately 1672 m^2 on three city blocks, containing three 37-story high-rise office towers, two mid-rise office structures, and a multi-purpose conference center that will seat 1,800 people. The design aim was to build a community; therefore, urban design standards played a significant role in the project, stressing ground-level activity and variety in building character. The design includes an open park, a two-way cycle track with individual entrances for bicycle commuters not near the garage or cargo dock, and tower curtain wall systems reaching upward to screen rooftop mechanical paraphernalia. During the day, Amazon keeps the spheres at 21.2 degrees and 60 percent moisture, while at night, the temperature will average 12.7 degrees and the humidity 85 percent, which would be optimal for the cloud forest plant varieties it has collected (Wingfield, 2016).

One of the primary points of the project is that Amazon wants to use nature on the inside to motivate employees. So the spheres are packed with a plant collection worthy of top-notch greenhouses, permitting Amazon employees to saunter through tree canopies three tiers off the ground (Wingfield, 2016).

The Google campus scheme in California and this venture are pioneer examples among small-scale proposals derived from Fuller's concepts concerning domed cities. These cases are good forecasters of how buildings of the future ought to look. Whether the same approaches could be used not only for working but also for living in them remains to be seen.

CALIFORNIA GOOGLE CAMPUS

The Google campus in California was conceived in various translucent canopies encompassing structures and outdoor areas, as shown in Figure 21. Designed by Danish architecture studio BIG, and London-based Heatherwick Studio, the campus is designed with a strong emphasis on the natural environment (Cameron 2015) and proposes controlling the environment inside the dome, while letting natural daylight and ventilation throughout the facility. A giant glass dome with internal canopies is meant to regulate "indoor temperature, air quality, and sound and to bring into the light a new model of working spaces" (Johnson, 2015). This structure consists of an 18.6-acre project site, intending to create lightweight block-like designs that can be transplanted around rather than investing in long-lasting buildings. Indoor and outdoor spaces have been entirely developed,

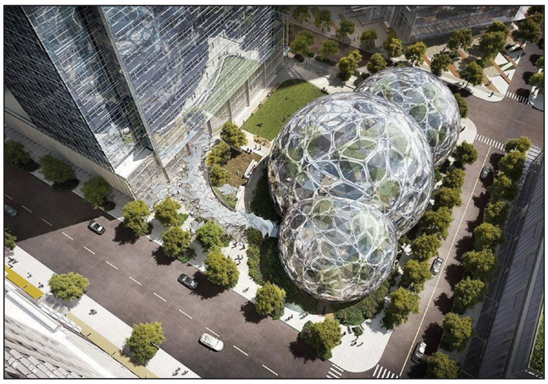


Figure 20 Amazon Biodome (Wired, 2022).

Figure 21 California Google Campus (Bloomberg, 2021).

encompassing natural habitats and vegetation (Cuevas, 2020). There are 1,200 parking spaces, 660 long-term bicycle parking spots, 400 short-term bicycle spots, and 400 spots for shared bike parking.

This project, which is still under construction, is deemed a small-scale concept of Fuller's domed cities, which, together with goggle biodome, concurrently signals the start of domed cities into practice.

DOME OVER CELJE

Dome over Celje is a conceptual project in the city of Celje-Slovenia that attempts to address the issues in this paper. The selected city of Celje (the third-largest town in Slovenia) came out of the contamination caused by the zinc factory, Cinkarna Celje, which makes this city and the surrounding towns some of the most contaminated city in Slovenia. Due to its environmental issues, the Celje area is known as "Slovenian Chernobyl" (STA 2019). The suggested area location for this Dome is close to the factory, as well as the industrial area of the town, where people must deal with the severe microclimatic environment and its severe pollution, noise, and heat island effects. The dome material structure of this project is an extensive ETFE-transparent membrane, which encompasses five buildings inside, thus offering a comfortable climate within the bubble, shelter from noise and pollution, and green spaces throughout the year, as shown in Figure 22 (a and b).

The vast Dome covers around 20,000 m2 within five different buildings, each six stories high. Each building has particular housing, managerial, and enlightening programs. The residential sector occupies the top three stories of each building. It is separated physically and visually from the semi-public area, with a "green" floor created as the shared space used only for residents. The transitional space between the buildings is conceived as a green public space with a botanical garden open to the public as shown in Figure 24 (a and b). The central idea of the layout, which is the division of the whole outer skin of the building from the inner facades, brings numerous environmental advantages. Firstly, both the unheated and heated entrances function as insulating compounds that serve to control the indoor climate. Opening flaps, for example, offers a well-controlled flow of fresh air into these spaces, allowing office windows to be opened to the concourse even in the winter for natural aeration. Second, since the interior walls are shielded from the immediate effects of the weather, prominent glass-frame façades can be increased in size – or eventually be open all the time, allowing for a better visual link with the outside. This result not only upholds a better sense of well-being but also helps to diminish the primary energy that would otherwise have been required.

The Dome's geometry is created in a way that helps to meet the thermal constraints. It was derived from the urban context, allowing, at the same time, the summer-season cushion of heat that develops in the summer to be removed before overheating can arise. Avoiding overheating during the summer, the southern part of the Dome is suggested with an ETFE-coated version, thus helping to inhibit direct sunlight for the hot season shown in Figure 23. During the hot seasons, these stay open most of the time and function spontaneously as an inflow opening during overheated times. They also smoke and freshen the whole structure naturally throughout the year.

During the cold season, aeration is conducted by a series of brief freshening periods that interchange the air volume within a few minutes from the storage area where the winter temperature would not be under minus. This buffer zone will not only enhance the relationship between the surface area of the casing and the space capacity but also allow individual window ventilation throughout the year. This system ensures pleasant working and living spaces, which are hierarchically divided within the inner structure of the buildings. In addition, when the external temperature is appropriate, cool outside air can ultimately cool the technical service areas within the facilities, reducing the substantial amount of electrical energy necessary for mechanical preservation.

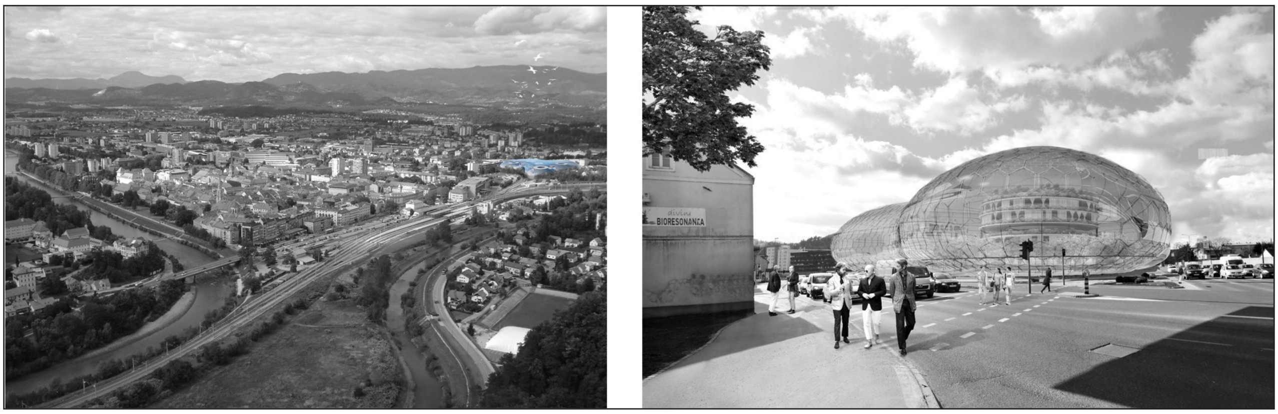


Figure 22 a Aerial view of Celje with Dome Montage. **b** Dome in urban context -Montage (Author).

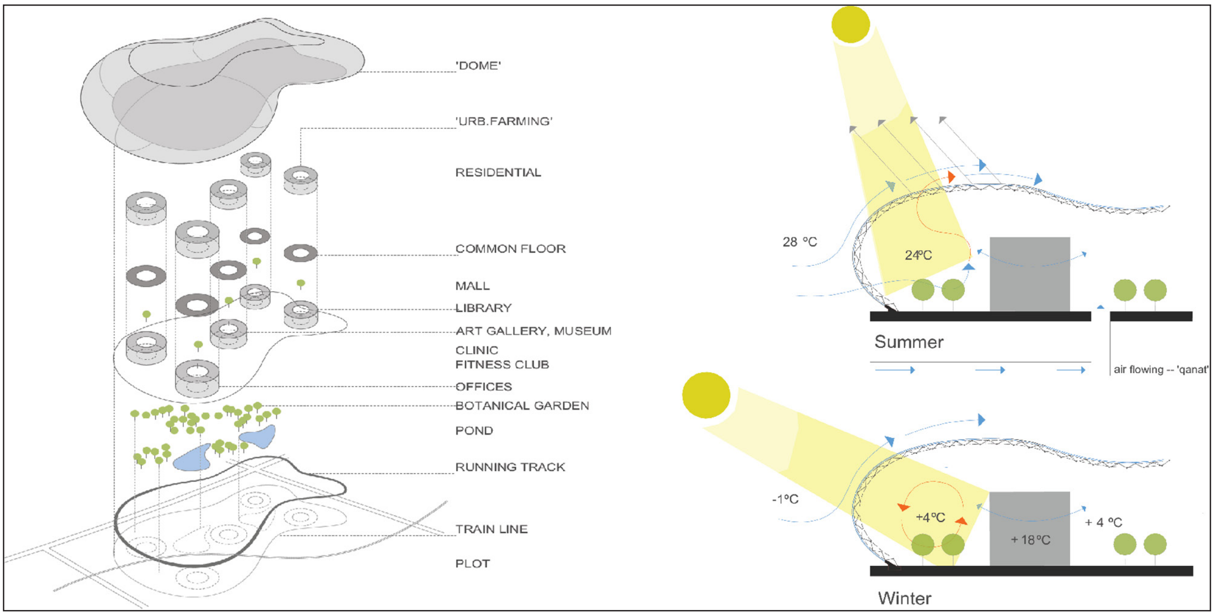


Figure 23 a Exploded Axonometric (Author). **b** Building Efficiency Concept (Author).

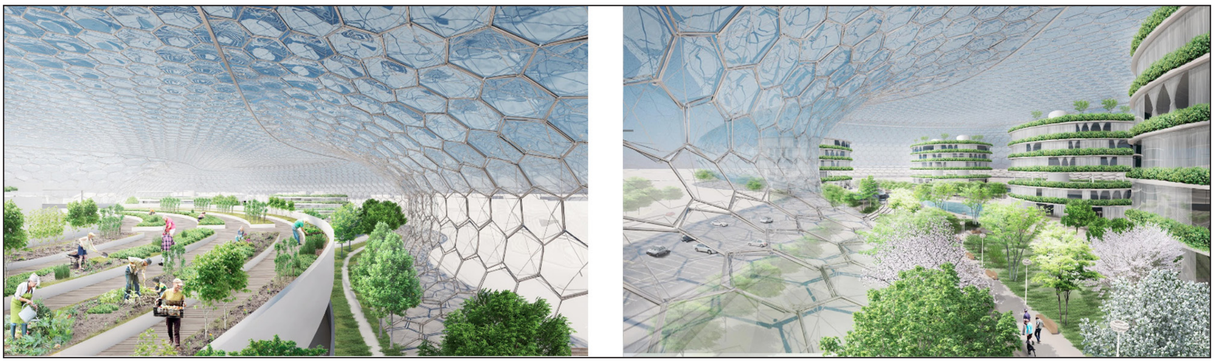


Figure 24 a and **b** Inside the Dome- Visualization (Author).

These are some benefits of employing such a concept in Celje, which would also aid the town's community. In this way, we would have three advantages derived from this methodology. The first is a comfortable environment for all seasons, the second is expending less on public services, and the third promotes the fight against global warming.

CONCLUSION

This paper presents the reviews of domed cities to deepen the understanding of the idea in practice, such as its approach in terms of architecture. Through this review, the architects have an opportunity to explore a broad spectrum of innovation by comparing today's achievable statuses against the possibilities generated by domed cities. This study provides a comprehensive overview of the need for domed cities in the face of pollution as one of the main concerns in many European cities. As a result, the significance of the reviews of the existing projects is focused on their conceptual quality. In emerging cities, innovative visions are needed to reduce environmental effects while providing places that increase social cohesion or help accelerate human interaction to improve the quality of life for an ever-increasing percentage of the world's population. The dome construction technology has diversified and is also used for civic spaces such as community shelters and faith centers. The dome construction resilience helps envision how it might be used in dome district design, such as bulk warehouses, community shelters for extreme weather events, and even more mundane uses like museums and gymnasiums. The fact is that we would not be able to stop climate change and should not stop thinking. To survive, the architects proposed to make climate-controlled cities—domed cities. So this means that global warming, caused by human actions and almost unavoidable, is increasingly becoming a prime threat to humanity. This situation results in polluted, overcrowded, and noisy cities. The only solution is to employ domed cities in these urban areas. The concept of living under the Dome remains to be developed in theory and practice. The difficult climatic situation will push these concepts further into their advancement, leading to the improvement of new typologies that seem vital for humankind. These leanings will soon lead to a gradual renaissance for new ways of living.

ACKNOWLEDGEMENTS

I acknowledge the support of the German Research Foundation (DFG) and the Bauhaus-Universität Weimar within the Open-Access Publishing Programme.

COMPETING INTERESTS

The author has no competing interests to declare.

AUTHOR AFFILIATION

Blerim Lutolli, PhD Can. orcid.org/0000-0002-2075-5115
Bauhaus University Weimar, Faculty of Architecture and Urbanism, DE

REFERENCES

Adonina, AV. 2020. Utopia or reality: architectural and urban typologies in the future of cities. *IOP Conference Series: Materials Science and Engineering*, 775: 012002. DOI: https://doi.org/10.1088/1757-899X/775/1/012002

Ardley, N. 1982. *Fact Or Fantasy?* F. Watts.

Banham, R. 1965. A Home Is Not a House. *Art in America*, 2: 70–79.

Barthel, R. 2018. Frei Otto–Architecture and Concrete Utopia. *Journal of the International Association for Shell and Spatial Structures*, 59: 55–59. DOI: https://doi.org/10.20898/j.iass.2018.195.896

Bleiler, EF and **Bleiler, R.** 1990. *Science-fiction, the Early Years: A Full Description of More Than 3,000 Science-fiction Stories from Earliest Times to the Appearance of the Genre Magazines in 1930 : with Author, Title, and Motif Indexes*. Kent State University Press.

"Bloomberg – Are You A Robot?". Bloomberg.Com. 2022. https://www.bloomberg.com/news/features/2015-05-07/google-s-new-campus-architects-ingels-heatherwick-s-moon-shot.

Cameron, Ch. 2015. Google's new California headquarters is a greenhouse utopia by BIG and Heatherwick. *Inhabitat*. 6 March, 2015.

Chu, H-Y. 2018. The Evolution of the Fuller Geodesic Dome: From Black Mountain to Drop City. *Design and Culture*, 10: 121–137. DOI: https://doi.org/10.1080/17547075.2018.1466228

Cuevas, RA. 2020. Case Study: Google's Unique Canopy Styled Construction.

Cureton, P and **Dunn, N.** 2014. *Future of cities: a visual history of the future*.

Dalvesco, R. 2017. R. Buckminster Fuller, the Expo'67 pavilion and the atoms for peace program. *Leonardo*, 50: 486–492. DOI: https://doi.org/10.1162/LEON_a_01157

Dinani, AT, Sadeghi, S and **Lourenço, PB.** 2019. A Double Dome Through The Ages. In: Aguilar, R, Torrealva, D, Moreira, S, Pando, MA and Ramos, LF (eds.), *Structural Analysis of Historical Constructions*. Cham: Springer International Publishing. pp. 87–95. DOI: https://doi.org/10.1007/978-3-319-99441-3_8

Duerden, N. 2010. A warren of streets: Eco-City 2020. *The Independent*. 03 December, 2010.

Franzén, I, Nedar, L and **Andersson, M.** 2019. Environmental Comparison of Energy Solutions for Heating and Cooling. *Sustainability*, 11: 7051. DOI: https://doi.org/10.3390/su11247051

Fuller, B. 1962. Technology and Futuristic imagery in the work of Richard.

Fuller, B. 1972. The Smith Tapes: Lost Interviews with Rock Stars & Icons 1969–1972. Edited by Ezra Bookstein. Princeton Architectural Press 2015.

Fuller, RB. 1969a. *Operating manual for spaceship earth*. New York.

Fuller, RB. 1969b. *Utopia or oblivion: The prospects for humanity*. Estate of R. Buckminster Fuller.

Geere, D. 2018. Russia plans domed city in Siberian mine. 17 November, 2018.

Hale, D. 1979. Domed City- Winooski, Vt., plans to live under giant bubble. *The Christian Science Monitor News Service*.

Hatch, A. 1976. *Buckminster Fuller: at home in the universe*. Dell Publishing Company.

Huebner, S. 2021. Earth's Amphibious Transformation: Tange Kenzo, Buckminster Fuller, and marine urbanization in global environmental thought (1950s–present). *Modern Asian Studies*, 1–30. DOI: https://doi.org/10.1017/S0026749X21000251

Johnson, S. 2015. BIG and Heatherwick Studio Design a New Google Headquarters. What the new Google campus in Mountain View, Calif., could look like. *Architect magazine*. February 27, 2015.

Keats, J. 2016. *You belong to the universe: Buckminster Fuller and the future*. Oxford University Press.

Khosrowjerdi, S, Sarkardeh, H and **Kioumarsi, M.** 2021. Effect of wind load on different heritage dome buildings. *The European Physical Journal Plus*, 136: 1180. DOI: https://doi.org/10.1140/epjp/s13360-021-02133-0

Kronenburg, R. 2014. *Architecture in Motion*. Routledge. DOI: https://doi.org/10.4324/9780203408964

Kibin. 2020. *Society and culture of an imaginary island in utopia by sir thomas more*. [Online]. Available: http://www.kibin.com/essay-examples/society-and-culture-of-an-imaginary-island-in-utopia-by-sir-thomas-more-EaK1nVRx [Accessed].

Lecuyer, AW, Liddell, I, Lehnert, S and **Morris, B.** 2008. *ETFE: Technology and Design*. Walter de Gruyter GmbH. DOI: https://doi.org/10.1007/978-3-7643-8624-5

Likitswat, F. 2019. Future Cities: New Generation's Visions of Sustainability Concepts and Models. *Future Cities and Environment*, 5. DOI: https://doi.org/10.5334/fce.61

Loudon, JC. 1824. *An Encyclopedia of Gardening Comprising the Theory and Practice of Horticulture, Floriculture, Arboriculture and Landscape-gardening*. Longman: Hurst, Rees, Orme, Brown and Green. DOI: https://doi.org/10.5962/bhl.title.29708

Lovelock, J. 2000. *The ages of Gaia: A biography of our living earth*. USA: Oxford University Press.

Markham, V. 1950. Joseph Paxton and His Buildings. *Journal of the Royal Society of Arts,* 99: 67–84.

Marks, RW and **Fuller, RB.** 1973. *Dymaxion World of Buckminster Fuller*. Anchor Books.

Mccormack, C and **Phillips-Hungerford, JT.** 2019. A Dangerous Precedent; the Geodesic Dome as a Credible Space Architecture Typology. *70th International Astronautical Congress, IAC 2019*. International Astronautical Federation, 50118.

"Montreal Biosphère of 1967/Buckminster Fuller". In *ArchEyes*. April 9, 2016, https://archeyes.com/montreal-biosphere-1967-buckminster-fuller/.

Noakes, CT. 2021. Montreal Biosphere. *The Canadian Encyclopedia*. 29 December, 2021.

Oliva Salinas, JG, Mendoza, M and **Meza, EG.** 2018. Reflections on Frei Otto as mentor and promoter of sustainable architecture and his collaboration with Kenzo Tange and Ove Arup in 1969. *Journal of the International Association for Shell and Spatial Structures*, 59: 87–100. DOI: https://doi.org/10.20898/j.iass.2018.195.900

Pawley, M. 1990. *Buckminster Fuller*. Taplinger Publisher. Co.

Peck, J. 1979. *Dome Idea called 'Ridiculous, Fabulous'*. Burlington Free Press. November 18, 1979.

Ponte, A. 2009. François Dallegret in Conversation. *AA Files-Architectural Association*, 28.

Riffat, S, Powell, R and **Aydin, D.** 2016. Future cities and environmental sustainability. *Future Cities and Environment,* 2. DOI: https://doi.org/10.1186/s40984-016-0014-2

Rose, S. 2018. Minnesota Experimental City: the 1960s town based on a comic strip. *The Guardian*. 05 November, 2018.

STA. (2019, October 23). *Pollution makes celje "Slovenia's Chernobyl"*. Slovenia. Retrieved March 22, 2022, from https://www.total-slovenia-news.com/lifestyle/4808-pollution-makes-celje-slovenia-s-chernobyl.

Sterling, S. 2010. Learning for resilience, or the resilient learner? Toward a necessary reconciliation in a paradigm of sustainable education. *Environmental Education Research*, 16: 511–528. DOI: https://doi.org/10.1080/13504622.2010.505427

Terio, O and **Honkanen, J.** 2013. Environmental Impact of Building Construction Projects in Northern Europe. In *Bo-Ricerche E Progetti Per Il Territorio La Citta El Architettura,* 4: 29–38.

Tigan, MT. 2005. *Citizen Participation in United States Department of Housing and Urban Development Programs: From the Great Society to the New Federalism.* University of Massachusetts Amherst.

Toorn, MWMVD. 2017. Design principles of botanical gardens. *Acta horticulturae*, 1189: 323–328. DOI: https://doi.org/10.17660/ActaHortic.2017.1189.62

"The Winooski Dome". *Weird Universe*. 2022, https://www.weirduniverse.net/blog/comments/winooski_dome.

Wallace-Wells, D. 2021. Doom, faith and sabotage: A cause as large as climate change requires a broad coalition of voices. *TLS. Times Literary Supplement*, 3–6.

Whitehead, R. 2021. Frei Otto's Pneumatic Experiments for Humanitarian Design. *Building Technology Educator's Society,* 2021. 19.

Wildermuth, TA. 2008. *Yesterday's City of Tomorrow: The Minnesota Experimental City and Green Urbanism.* University of Illinois at Urbana-Champaign.

William Delisle, H. 1881. *Three Hundred Years Hence*; or, *A Voice from Posterity*.

Wingfield, N. 2016. Forget Beanbag Chairs. Amazon Is Giving Its Workers Treehouses. *The New York Times,* 201: 10.

Wurm, J. 2007a. *Glass Structures: Design and Construction of Self-supporting Skins* [Online]. Birkhäuser. DOI: https://doi.org/10.1007/978-3-7643-8317-6

Wurm, J. 2007b. *Glass Structures: Design and Construction of Self-supporting Skins*. Birkhäuser. DOI: https://doi.org/10.1007/978-3-7643-8317-6

Wired. 2022. https://www.wired.com/2017/05/amazons-expansive-biodomes-get-first-9000-plants/.

TO CITE THIS ARTICLE:
Lutolli, B. 2022. A Review of Domed Cities and Architecture: Past, Present and Future. *Future Cities and Environment,* 8(1): 9, 1–15. DOI: https://doi.org/10.5334/fce.154

Submitted: 24 March 2022 **Accepted:** 25 August 2022 **Published:** 07 September 2022