Climate change related urban transformation and the role of cultural heritage

Matthias Ripp & Christer Gustafsson
(Eds.)

Foreword by Claire Cave

Il Sileno Edizioni

Geographies of the Anthropocene

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Editors

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Geographies of the Anthropocene

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The book series “Geographies of the Anthropocene” edited by the Scientific International Publisher “Il Sileno” (Il Sileno Edizioni) will discuss the new processes of the Anthropocene epoch through the various worldviews of geoscientists and humanists, intersecting disciplines of Geosciences, Geography, Geoethics, Philosophy, Socio-Anthropology, Sociology of Environment and Territory, Psychology, Economics, Environmental Humanities and cognate disciplines.

Geoethics focuses on how scientists (natural and social), arts and humanities scholars working in tandem can become more aware of their ethical responsibilities to guide society on matters related to public safety in the face of natural hazards, sustainable use of resources, climate change and protection of the environment. Furthermore, the integrated and multiple perspectives of the Environmental Humanities, can help to more fully understand the cultures of, and the cultures which frame the Anthropocene. Indeed, the focus of Geoethics and Environmental Humanities research, that is, the analysis of the way humans think and act for the purpose of advising and suggesting appropriate behaviors where human activities interact with the geosphere, is dialectically linked to the complex concept of Anthropocene.

The book series “Geographies of the Anthropocene” publishes online volumes, both collective volumes and monographs, which are set in the perspective of providing reflections, work materials and experimentation in the fields of research and education about the new geographies of the Anthropocene.

“Geographies of the Anthropocene” encourages proposals that address one or more themes, including case studies, but welcome all volumes related to the interdisciplinary context of the Anthropocene. Published volumes are subject to a review process (**double blind peer review**) to ensure their scientific rigor.

The volume proposals can be presented in English, Italian, French or Spanish.

The choice of digital Open Access format is coherent with the flexible structure of the series, in order to facilitate the direct accessibility and usability by both authors and readers.

Contents

11. The medium technology of the building cultural heritage

Friedrich Idam[1], Günther Kain[2]

Abstract

This paper deals with the huge sustainability potential of our building heritage. On the basis of current research projects, it is shown how historical solutions for building conditioning can be recorded, evaluated and refined using the methods of applied building research. In the course of climatic changes, the requirements of building conditioning shifts increasingly from heating to cooling. From this point of view traditional building envelopes and cooling systems gain importance, also in the global north.

As an alternative to the currently favored high-tech innovation of "smart buildings" and their technological consequences, targeted ex-novation in the form of re-implementation of technologies proven in the past could prove to be more sustainable in the long term.

This does not mean a "back to the Stone Age," but rather the most comprehensive possible evaluation process of medium technologies and their long-term efficiency potential. Mid-range technologies, which have already proven their functionality over centuries, hold the potential for a climate-compatible technological turnaround that can be implemented worldwide on the basis of mankind's building heritage.

Keywords

Simple smart buildings, built cultural heritage, sustainable buildings, building innovations, medium technology

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1. Introduction

The ongoing worldwide climatic changes and the economic crisis require the development of simple, resilient, but above all cost-effective construction techniques, building types and building operating systems. This ambitious profile of requirements is already comprehensively represented by our building cultural heritage. In contrast to short-lived and expensive high-tech buildings, however, traditional building techniques are also accessible to the population of underdeveloped regions. The approach presented assumes the most open and broad view possible into other times and in other regions, learning from the building cultural heritage of mankind. This can provide the basis for a paradigm shift in construction.

2. Simple Smart Buildings

For example, one can learn from the proven strategies of those regions that have already had a climate like the one that seems to solidify in Europe for centuries, to construct resource-efficient cool buildings. The mainstream approach on the other hand, is the innovative development of building technology, which is considered a promising solution strategy. The development objective are fully automated "intelligent" buildings, so-called "smart buildings". However, the short life cycles of such systems are often overlooked due to rapid technological change. In addition, technical innovations often increase resource consumption. As early as in the second half of the 19th century, the economist William Stanley Jevons recognized that technical innovations reduce operating costs below tipping points and thus lead to a disproportionately higher consumption of these resources. (Jevons 1866) This paradox is also referred to in technical literature as rebound effect. As a counter model, the re-implementation and moderate further development of historically proven technologies is presented here. The combination of empirical knowledge and applied construction research can be the starting point for sustainable building strategies, whose long-term consequences are already available as real findings.

This approach is by no means intended as a "return to the Stone Age," but rather as a comprehensive evaluation process of intermediate technologies and their long-term efficiency potential. The concept of intermediate technology, which was already coined in the 1970s, offers the potential for a technology turnaround that can be implemented worldwide. (Schumacher 1973, Kohr 2007)

For the generations before us, it was obvious to create durable buildings by simple means and minimal energy input, whose architectural elements were adapted to the site climate. This ensured the constructive protection and long-term existence of a building. The preserved building fabric of the World Heritage Sites, which is still inhabited, represents a positive selection: These are the best houses, they are the ones that have survived a tough evolutionary process. These outstanding buildings have simply functioned long and well. They are simple and smart houses yet, referred to as "Simple Smart Buildings".

In the various World Heritage Sites, locally available building materials have been used to develop resilient building constructions and building types that have survived the centuries and for this very reason still offer a high quality of use. A promising approach to the development of simple and resilient building techniques, as well as long-lasting building types and building operating systems, lies in the concept of Simple Smart Buildings, which draws on the potential of our building cultural heritage.

3. Methodology and relevance

As part of the ICOMOS Austria research network, several research projects are currently being carried out with the support of the Cultural Section of the Austrian Federal Ministry for Arts, Culture, the Civil Service and Sport, taking into account the Simple Smart Buildings approach. Applied building research is used meaning scientifically measuring various phenomena in-situ in and on buildings. The approach enables the evaluation of hypotheses and fact-derived conclusions. In specific, this included the metrological evaluation of thermal transmittance in historic window constructions, the exploration of the potential use of peat moss (Sphagnum) as a sealing and insulation material, the reassessment of thermal qualities of solid masonry under changing climatic conditions, the minimally invasive installation of infrared shading screens in historic attics, and the cooling efficiency of historic air well systems.

These topics can be understood as examples how the "Simple Smart Building" approach could be used for practical applications. The strength of the concept is that it combines the efficient use of resources - both materialistic and energetic and a positive social dimension by empowering people to build and maintain their build environment by themselves. Additionally, simple smart buildings provide the means to develop the building stock in a more sustainable use. Finally, the integrative consideration leads to a more resilient society which has the means at its command to adapt to an ever-changing environment.

4. Window constructions

The aim of the window research project is to demonstrate the significance and competitiveness of existing and new wooden box-type windows compared to multi-pane insulating glass windows using a holistic life cycle-oriented approach. The preservation of valuable architectural substance should thus be secured and its replacement by industrially manufactured windows should be avoided due to a one-sided, only short-term energy-focused consideration.

Historic double windows are still in use, but since the 1970s they have been increasingly replaced by so-called thermal windows made of wood, metal or plastic. The primary argument for the window replacement, apart from the durability of the surface coating, is the high thermal transmittance of double windows. The heat transfer in a stationary state is described by the U-value, which quantifies the area-related energy flow through a building component at a defined temperature difference from the inside to the outside. For the historic double windows, however, it is not the measurement results on the actual building stock that are used, but rather fictitious substitute values (default values) defined in a standard, which are two to three times the laboratory values of the industrially manufactured thermal windows. As measurements on existing double windows showed, properly renovated box-type windows have lower U-values than 2.5 W/m^{2}K, defined in most standards and simulation programs. Another aspect is that the inert gas filling of thermal insulation glass begins to diffuse out after latest 30 years, and heat losses through the glass surfaces increase with the course of time (Kain and Idam 2023a). In order to be able to determine the actual thermal transmittance of windows in situ, the development of a measurement method has now been tackled, which can be used in situ on the real object (Kain et al. 2017). This procedure creates the basis for developing a validated, comparative life cycle assessment of different window systems "from cradle to grave" in terms of energy consumption for specific objects. The validation of this in-situ measurement method will be carried out in a research project launched in 2022 with extensive comparative measurements at the standard-compliant window test facility of the Municipal Department 39 in Vienna. On the one hand, the U-values are determined in a test stand by official experts in accordance with the standard, and on the other hand, a series of sensors are additionally attached to the test window in order to also be able to carry out the deductive U-value estimation as a comparison to the test result.

In total, three maintenance states have been mapped so far: the unrefurbished window in its original state, the window with adhesive seals on the inner sash, and the window with taped joints and inserted window cushion. The initial results of the evaluation show that the U-value of the unrefurbished window is close to the default value of 2.5 W/m²K, the installation of seals on the inner sash leads to a reduction to approximately 2.0 W/m²K, and the complete sealing of the joints causes only a slight improvement to approx. 1.9 W/m²K, but this results in classic problems of condensation on the outer sashes. In the next step, scheduled for 2023, the results of the in-situ method will be compared with the test rig results to assess its validity. It is expected that the effectiveness of potential remediation measures can be derived from the measurement data obtained.

In areas with distinct winter and summer climates, there are very different demands regarding the building envelope over the course of the year. Progressive global warming also requires effective shading systems for historic buildings and their historic window stock, which do not impair the values of the monument. Most of the time varying seasonal requirements are compensated by means of technical air-conditioning systems.

Figure 1: Historic double window (end 19th century) in the test stand of the of the Municipal Department 39, Vienna, window taken from the stock of the convent Mauerbach, photo Peter Hunger.

Alternatively, this compensation can also be achieved by seasonally changing adaptation of the building envelope. Until the middle of the 20th century, window constructions were equipped with an additional sash during the cool season to prevent energy loss, and with blinds during the warm season to prevent excessive solar radiation and improve ventilation. Transforming this approach for modern buildings offers an interesting field of research with future potential. Therefore, in the course of the 2022 window research project, the development of a variable external shading system, based on empirical knowledge, was also tackled (Kain and Idam 2023b). With the help of the validated in-situ measurement method, it should also be possible to determine the effect of different shading systems non-destructively.

5. Peat moss (Sphagnum)

The examination of historical building structures not only provides information about past working techniques, but also unveils materials that have stood the test of time. Sphagnum moss is found as a joint sealing material in objects as diverse as drift chalets, log buildings, and wooden boats. Knowledge about sealing the joints of historic wooden structures has current relevance, as there is demand for durable and ecologically compatible joint sealing solutions in the growing market segment of timber constructions.

In the past, sphagnum was simply extracted from local, near-natural bogs, whereas now the sustainable extraction of this raw material has been researched for several decades. Under natural conditions, sphagnum mosses grow primarily in acidic to sub-neutral, nutrient-poor environments, such as those found mainly in intact raised bogs. The water table is the main determinant of sphagnum moss growth; sphagnum mosses can therefore also grow in wet forests or wet meadows, but they are most commonly found in raised bogs (Krisai 1999). In wet, natural bogs, sphagnum peat mosses are the main contributor to the growth of a raised bog, which can grow about one millimeter (mm) per year (Krebs et al. 2015).

For several decades, research has been conducted into the cultivation of peat mosses in so-called paludicultures (“palus” - Latin for “swamp, morass”). This involves the rewetting of drained and degraded peatlands that have been used for agriculture or forestry. After rewetting, peat mosses can be applied to a former raised bog area and harvested after an average of four years (Sphagnum farming). After harvesting, these grow again and can be harvested every few years. Current studies in Germany show Sphagnum yields averaging 36 tons of dry matter per hectare and year. By rewetting and keeping the water table high, Sphagnum farming areas can store carbon again (Gaudig et al. 2018).

The use of moss can be documented in the Upper Austrian Salzkammergut from written sources as early as the middle of the 18th century (Vasold 1768). Before the dried moss was inserted into the joints to be sealed, it was spun into a plait, a kind of sealing cord. This is evidenced not only by the actual finding of a sealing cord in the joints of an 18th century log rooming, but also by oral tradition.

Figure 2: Beringstadel, Gosau, block carpentry 18th century. Sealing cord made of sphagnum. Condition 2017, photo: Stefanie Mandl.

The historic constructions all have wedge-shaped joints into which moss was pressed with a positive fit. On the narrower inner side of the joint, a narrow trapezoidal filler strip was first inserted to prevent the moss from being pressed through the joint. The next step was to insert the sphagnum, which was spun into a sealing braid and compacted with the help of a wider, also trapezoidal press bar, which was fixed with U-shaped clamps made of wrought iron. As soon as this construction comes into contact with water, all the construction elements absorb moisture and swell in the process. In this way, the geometry of the construction elements and the swelling behavior of the materials automatically regulate the degree of tightness of the joint.

Also, in the stone bases of the alpine huts, the joints of these dry-stone walls were stuffed with moss (Stadler 1984).

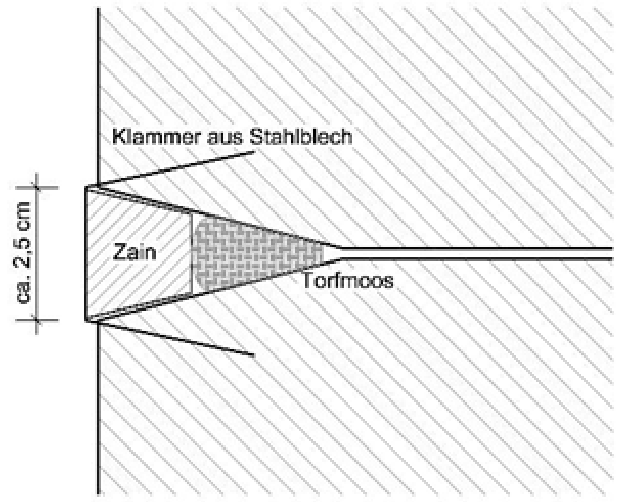

Figure 3: Detailed section through the sealing of the joints of block carpentry. Drawing Friedrich Idam.

The technical and physical properties of Sphagnum were investigated at the HTBLA in Hallstatt and the Salzburg University of Applied Sciences. It was found that Sphagnum has an equilibrium moisture content of 18.3 % (standard deviation 0.4 %) in a climate of 20 °C and 65 % humidity. This climate leads to an equilibrium moisture content of about 12 % for wood. The significantly higher equilibrium humidity is caused by the special structure of the hyaline cells of the moss, which enables the high-water storage capacity of the plants. In the experimental setup, gut-dry sphagnum moss was stored in water until maximum swelling. In this process, the moss is able to absorb an average of fourteen times its dry weight in water, with a simultaneous significant increase in volume. This behavior is very interesting for the sealing of joints on buildings in the alpine climate, since the high relative humidity that occurs more frequently in summer leads to an increase in the equilibrium moisture content of the moss and an associated swelling. Due to the languid moisture balance of natural wall materials (wood, clay, brick), this condition can persist well into the heating season. The highly hygroscopic moss could also buffer potentially occurring condensate in the joints during winter and accelerate drying to the outside due to its diffusivity (Kain et al. 2019).

Particularly relevant for use as a thermal joint sealant is the thermal conductivity of peat moss. This was determined for various raw densities as part of a research project at the Salzburg University of Applied Sciences. It was found that the thermal conductivity at a density of 50 kg/m³ is only 0.036 W/(m*K), which is comparable to that of mineral wool or polyurethane foam. Thus, the insulating capacity of moss is on a par with recent joint insulation materials and also offers itself as a renewable raw material for thermal insulation panels (Kain et al. 2021, Morandini et al. 2022).

6. Stone walls

Solid masonry made of stone has been the universal wall builder for thousands of years. It combines the advantages of using regionally available raw materials with those of thermal storage mass. With the traditional binder lime, durable walls can be built with a moderate ecological footprint. Unlike cement, lime permanently binds atmospheric CO_2 in its curing process.

Figure 4: Room extension and work stone extraction, photo Gottfried Buchegger.

Unrendered stone-faced walls characterize the image of the World Heritage cultural landscape Hallstatt-Dachstein/Salzkammergut. The necessity of a secure foundation makes the historic stone walls follow the natural course of the rock formations, whereby the retaining wall with its buckling edges and curvatures takes over the motif of the terrain. These historic stone retaining walls intuitively show the forces they are capable to absorb. Masonry that primarily absorbs vertically acting forces shows clearly legible horizontal bearing joints. Retaining walls, which must also withstand horizontal loads, slope against the earth pressure with a 10 to 20 % slope, the so-called run-up.

The bearing joints of the retaining walls run horizontally in long courses for several meters, then jumping against each other in height. The course heights change and tend to decrease towards the top. The largest stones are located at the base of the walls, and towards the top the stones become smaller, creating a perspective effect in conjunction with the slope of the walls, which makes the wall appear higher. Historic stone walls in the Salzkammergut are also characterized by the fact that the entire visible surface is executed with narrow joints and level. (Idam and Kain 2020)

Figure 5: Plinth masonry of the Schafferstadel Hallstatt. Photo Friedrich Idam.

The main physical disadvantage of dense, non-porous stone material for use in building construction is its good thermal conductivity. Studies of masonry stock show that masonry structures for residential buildings differ in stone size and joint design from purely engineered retaining walls. Smaller bricks, wider joints made of air-lime mortar and clay bricks mixed into the bond significantly increase the porosity of the wall structures. As a result, both their thermal conductivity and vapour diffusion resistance decreases. In wall inventories at the Hallstatt-Dachstein/Salzkammergut World Heritage Site, there is also evidence of organic mortar additives in the plaster, such as sawdust, which further reduce thermal conductivity. Whereas until a few years ago stone walls in residential buildings were nevertheless perceived as too cold in the winter months, they now offer a pleasantly cool indoor climate in the increasingly hot summers – entirely without energy-intensive cooling technology. This is because the thermal daytime peaks are shifted to the cool nighttime hours by the inertia of the thermal storage mass of the solid stone walls.

7. Infrared shading

Urban World Heritage sites, with their stock of important buildings, are often located in inner-city heat islands, where summer temperatures rise at an above-average rate year after year. For these buildings, alternative cooling systems must be developed that function in a self-regulating manner, preferably without the use of operating energy, and that leave the fabric of the monument as untouched as possible.

As initial tests in the attic of Vienna's Burgtheater in August 2020 have shown, quite effective cooling effects can be achieved with lightweight membranes applied in the roof space. In the specific case, the energy radiation of the heated roof cladding was "shaded" towards the inside (Kain et al. 2022). The term "shading" here refers to shielding the invisible infrared radiation of the solar-heated roof cladding. Therefore, infrared shading is effective even in unexposed roof spaces. In the first test, membranes in the form of fire-resistant fabric sheatings were used as shielding elements. Cooling effects on the shaded surfaces (compared to the existing roof cladding) of up to more than 15 K could be proven by measurement. It would therefore appear to be expedient to pursue the infrared shading of roof spaces further.

The physical mechanism of this finding can be explained by the "Stefan-Boltzmann relationship". According to this, the thermal radiation power of a body increases in proportion to the fourth power of its absolute temperature. However, if a cooler surface is placed in front of the hot roof cladding on the inside, the heat radiation to the inside can also be reduced exponentially.

In order to maintain or further increase this effect, the area in front of it should be kept permanently cool, which is quite possible given the low mass of ultralight under-roof elements. In two pilot projects based on these initial findings, the material of the canopy elements and economically and ecologically feasible cooling methods were evaluated. As a cooling medium, naturally pre-cooled air flows that originate from an air well or are guided into the building as a wind flow will be in the focus of further investigations.

The first step is the development of a test design for the valid evaluation of ultra-light sub-roof elements. Materials such as thin plywood or membranes in form of fire-resistant fabric sheets can be considered. It will be necessary to clarify the influence of different materials, their weight and the combination of different material layers. In any case, the ultra-light sub-roof elements must be fire-resistant, easy to install and, if necessary, easy to remove again without affecting the historic structure. With infrared shading, a simple, effective and economical improvement of the thermal quality of roof spaces of valuable historic buildings can be achieved without interfering with their substance, static structure and external appearance. Infrared shading could significantly reduce the daily cyclical temperature fluctuations of upper floor ceilings and their damaging effects on the equipment and architectural surfaces below (Kain et al. 2022).

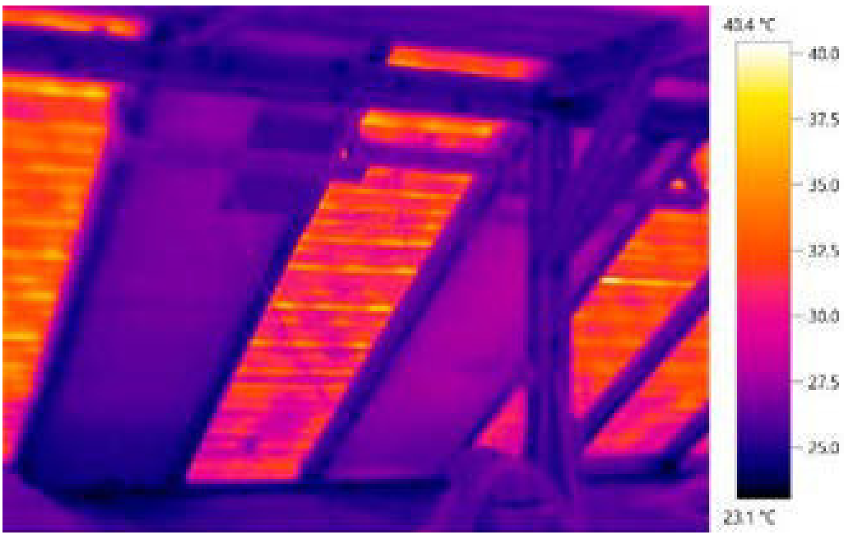

Figure 6:
Infrared shading Stadel Bad Goisern. Thermography Günther Kain.

8. Air fountain

Storing large amounts of energy over several months is one of the key challenges on whose sustainable solution the success of the energy transition of the 21st century will depend. The value of our building heritage is based not only on its external appearance, but also on the evidently resilient substance and the building technology experience accumulated over centuries. Historic storage and distribution systems for building conditioning are still in operation, enabling efficient and sustainable temperature and humidity balancing over time. In this context, the building services and the building fabric form a systemic unit whose elements are conceived holistically and interact with each other. The utilization cycles of these complex, largely self-regulating building service systems driven by air pressure differences span centuries. Such systems were already known in ancient times and spread from Persia through the Ottoman Empire and the Balkans to Western Europe.

As a transport medium, a large preconditioned air volume moves slowly through wide shafts, which are located in the interior walls and are connected to the rooms by optionally closable openings. Equilibrium states of temperature and humidity settle between the air and the masonry. In this way, the entire core of the building is preheated in winter and kept cool in summer, while maintaining a constant humidity level in the interior. These combinations of shaft systems with an upstream earth mass storage tank, which can be charged or discharged by means of the air flowing through it, are called air wells. Due to the considerable storage potential of the earth masses around and under the building, seasonal shifts of the extreme values from summer to winter or vice versa are possible.

In the diurnal cycle, the thermal daytime peak of the early afternoon is analogously shifted to the cool nighttime hours by the continuous air circulation, while condensate that has formed in the surface area of the shafts in the early morning hours evaporates during the day, releasing cooling energy and humidifying the dry air.

The extent to which masonry can store energy and moisture depends not only on its mass, but also on the choice of building materials. Traditional building materials such as brick, lime plaster, wood or clay are not only excellent at storing energy, but also have a moisture-regulating effect due to their porous structure. The specific surface area of porous materials, in contrast to dense materials, is many times greater. This accelerates the intensity of physical exchange processes, such as heat transfer or evaporation.

Since the humidity of the outside air is significantly higher in summer than in winter, it can be used in air wells for cooling. Capillary condensation plays an essential role in this process. In porous materials, similar physical laws apply as in capillaries. Different pressure conditions prevail in these fine structures than in the surrounding atmosphere. This causes water to rise upward in capillaries against gravity and water vapor to liquefy more easily. However, water also flows there, both in liquid and vaporous form, always from warm to cold. When cool night air passes through the air well, the surfaces in the wells become colder than the core of the masonry. Moisture stored in the masonry moves toward the cold surface and the water vapor condenses. From there, the water moves in liquid form to the surface, where it is absorbed by the air flow and the water evaporates in the process. The transition from the liquid to the vapor state, at atmospheric air pressure, extracts energy from the surroundings, so that both the air flowing through and the surfaces of the shafts are cooled additionally.

Important buildings on the Ringstraße in the historic center of Vienna, a World Heritage Site, such as the State Opera House, the Stock Exchange, the Parliament Building, the Burgtheater, the two Court Museums and finally the Corps de Logis - the imperial apartments in the new Hofburg, were equipped with a series of large air fountains unique in the world. The physician and air hygienist Carl Böhm planned these installations, some of which are still in operation today, from 1861 until the turn of the 20th century.

Figure 7: Air vent "Blasengel" on the Burgtheater, Vienna. Photo Friedrich Idam.

The air well system of the Burgtheater is best preserved from the examples mentioned. The air is led from the intake in the Volksgarten to the exhaust opening above the roof. The supply air sinks through a shaft six meters in diameter to the third basement level. From there, a one hundred meter long tunnel leads the supply air through the earth reservoir to the ventilation center, where it is now further specifically conditioned and distributed throughout the building via a highly complex system of corridors, shafts and chambers, and finally discharged via roof at the “bubble angel”. This popular name derives from the wind vane, visible from afar, which is executed as a figural sheet-metal work. This outlet work represents both the artistically designed roof crown of the Vienna Burgtheater and a fascinating technical monument with future potential. For more than 130 years, wind energy has continuously turned the huge outlet opening of the exhaust air duct to the lee in a self-regulating and trouble-free manner, so that the exhaust air flows out freely (Idam et al. 2023).

9. Wind towers

When we think of wind energy, we probably first think of the large wind turbines that are currently being installed in the landscape. But wind energy can also be used in a simpler and perhaps more sustainable way shown by the control system of the “bubble angel”. “” Another fascinating example are the “Badgirs”, wind towers that have spread from Persia throughout the Middle East. In the badgir, several physical phenomena are combined cleverly. These are mainly the dynamic pressure of the wind, the Venturi effect, the storage capacity of solid masonry, evaporative cooling and the chimney effect.

During a summer day, buildings are cooler inside than the outside air. This means that a chimney located inside the building is also correspondingly cool. The cool air becomes heavier and sinks in the chimney. The cooled air flows out through openings at the lower end of the chimney. At the upper end of the chimney, on the other hand, the sinking of the cold air creates a slight negative pressure through which the outside air is drawn in. If this suction is not sufficient, the wind can be used to drive the badgir. If the wind hits a surface in its way, the air accumulates there and an overpressure is created - the dynamic pressure. On a surface that is at an angle to the wind direction, the dynamic pressure deflects the wind. To catch the wind, all you have to do is placing a surface at the top of the chimney that is slanted 45 degrees. The wind flows horizontally against this deflecting surface and is forced down the chimney.

In this way, cool outside air enters the building even when the chimney has warmed up during the day and the air in the chimney rises. In the process, the chimney cools down and continues to draw cool air into the building with the onset of the chimney effect, even if the wind is then no longer blowing. During night, when the inside air temperature is higher than outside the shaft of a badgir can be used powered by the chimney effect whereupon the warm air moves upwards because of its lower density.

In its simplest design, a badgir consists of a shaft facing upwind and a second shaft facing downwind. In the supply air shaft, the cool air is captured and led into the building, while in the exhaust air shaft, the used, heated air is blown back upwards and released to the outside. This basic construction method is sufficient when one wind direction prevails. Where the wind frequently changes direction, we find more sophisticated designs, which then consist of four or even eight shafts, which enable wind capturing from several directions. The wind tower systems are controlled by empirical knowledge that has been passed down through generations. In a few simple steps, depending on the weather conditions, the indoor climate can be regulated by opening or closing certain shafts. (Roshanak 2018)

Towards the end of the 18^{th} century, the Italian physicist Giovanni Battista Venturi discovered that liquids and also gases flow faster when the flow channel narrows. What surprised him, however, was that the pressure at the constriction does not increase, but rather decreases. This has to do with the fact that the faster-moving molecules entrain the particles in their vicinity. This effect makes it easy to extract stale air from a room. Constrictions in the exhaust air shaft automatically create the necessary negative pressure, and the used air is extracted through openings in the shaft.

A wind tower is indeed a tower in its outer appearance and with its thick walls sometimes as large as a church steeple. Most wind towers in the Orient are built of clay and are impressive structures designed in many ways.

The storage capacity of the massive building structure of the badgir can compensate for the climatic differences between day and night. The same physical mechanisms as in the air wells of Vienna's Ringstrasse are used with porous structures of the clay in the badgir. This closes the chain of a transfer of medium technologies that goes back to the Baroque era and stands as a model for a sustainable problem-solving strategy.

10. Conclusion and outlook

Even in times of crisis, people build, but unlike in times of plenty, it is now necessary to use resources efficiently. The climatic changes underway around the world and the emerging economic crisis require the development of simple, resilient, but above all cost-effective construction techniques, building types and building operating systems. An interesting aspect of the "Simple Smart Buildings" approach is that it is a way to deal with phenomena of climate change and in the same time help to reduce the overall resource consumption of buildings.

From the experience gained from the examples discussed before, a limitation of the "Simple Smart Buildings" approach is that it requires an "out of the box" perspective in an early state of planning. In real life, very often in an early project phase decisions in favor of high-tech solutions are made which are likely to make a simple smart building impossible. Moreover, the realization of smart buildings requires skilled workers of which there is a lack off at the moment.

On the other hand, simple smart buildings can be realized with the people and materials available on site. This is a huge advantage making societies independent from global supply chains and giving local manpower its value. Also, the transferability of simple smart solutions is high. Therefore, best practice examples like presented before have the potential to inspire other projects on a global scale.

The idea has to be spread amongst experts and investors as it lacks huge lobbying efforts. This mainly because for tendency simple smart buildings are less dependent on building industry than modern high-tech buildings. As the use of simple smart technologies requires a multi-disciplinary planning approach, the most successful "marketing" activity for the idea probably is the training of engineers working in the field.

Our World Heritage represents the best and most durable intermediate technology, which not only holds the potential for a paradigm shift in industrial societies. Unlike short-lived and expensive high-tech systems, intermediate technologies are also accessible to broad segments of the world's population. And that is the basic idea of World Heritage: to bring about peace on the basis of the common heritage of all people.

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Starting with a systemic understanding of cultural heritage, climate-change related urban transformation processes are analyzed through a multi-disciplinary lens and methods that blend the arts, humanities, and sciences. Governance-specific topics range from relevant cultural markers and local policies to stimulate resilience, to a typology of heritage-related governance and the vulnerability of historic urban landscapes. A variety of contributions from the Americas, Asia, and Europe describe and analyze challenges and potential solutions for climate-change related urban transformation and the role of cultural heritage. Contributions focusing on innovation, adaptation, and reuse introduce the concept of urban acupuncture, adaptive reuse of industrial heritage, and how a historical spatial-functional network system can be related to a smart city approach. The potential role of cultural traditions for resilience is analyzed, as is the integration of sustainable energy production tools in a historic urban landscape. Examples of heritage-based urban resilience from around the world are introduced, as well as the path of medium-technology to address climate adaptation and prevention in historic buildings. The contributions emphasize the need for an updated narrative that cultural heritage can also contribute to climate adaptation and mitigation.

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