JAPANESE TRADITIONAL PATTERNS AS AN INSPIRATION FOR BUILDING-INTEGRATED PHOTOVOLTAICS (BIPV)

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Section 1, the Introduction.
Section 2 explores the importance of culture for architecture and sustainability.
Section 3 analyses cultural differences of light and shadow, as well as nuances in the perception of depth.
Section 4 introduces the current debate on the relation between patterns, parametricism and performance in architecture.
Section 5 explores recent architectural low-res pixellated design strategies, and the affine and inherent qualities of solar photovoltaic cells.
Section 6 provides case studies, results of an investigation into applying the inventory of local cultural assets, here Japanese traditional family crests, as an inspiration for technological innovation, here alternative patterns for solar photovoltaic panels.
And finally Section 7 records the main conclusions of this paper.

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Section 1. Introduction

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This paper reports the results of an investigation into applying the inventory of local cultural heritage, here Japanese traditional family crests, as an inspiration for technological innovation, here alternative patterns for solar photovoltaic (PV) panels.

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Building in the 21st century is driven by the need to embark on the paradigm of sustainable energy use and supply. This includes reducing the need for energy, maximising energy efficiency, saving non-renewable as well as harnessing renewable energy sources, to ultimately replace today's reliance on non-renewable energy sources. Zero-energy and carbon-neutral architecture are the goal. Photovoltaic (PV) systems are one way of energy generation from renewable sources, which can be easily integrated into buildings (BIPV), thus underlining a sustainable energy supply, which *"implies a local scale for energy sourcing"*.

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Integrated renewable energy generation is still all too often viewed as an added element stacked or patched on top, rather than as inherently belonging to and part of our environment.

> *"Energy is all. We are still largely unconscious of it, but our entire lives (both urban and rural) are driven by our access to energy (how we use it, why we use it, what sort of energy we use)."*

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In the words of Cedric Price, technology is maybe an answer, but we must not forget the question. As the answer, the technology of renewable energy generation, is readily available nowadays, a possible question was indirectly stated by Webb: *"our culture needs to internalise a new valuation of energy"*, hence the question for a cultural view on energy. While technology is a global phenomena, culture is rooted in the local, human scale.

"The essence of culture is in locality. There's any such thing as a global culture."

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Section 2. Culture for Architecture and Sustainability

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The struggle to shift the focus of current developments towards a sustainable one is happening with undiminished intensity in all fields and in architecture as well, both in the theoretical discussion and in the building industry. To visualize the concept of sustainability in its manifold depths, it is helpful to think of layers. The generally established three main pillars or layers without hierarchy are economy, society and environment. However, *"[...] the meaning of sustainability depends on the context, in which it is applied"*.

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The theoretical framework for architecture, that we are going to use, was suggested by Namba. While evolving the concept of architectural designs for his box-house series, Namba developed a theoretical approach that he calls the 'Four Layers of Architecture'.

A short explanation of the four layers …

At different times the layers had different importance. For instance Mies van der Rohe and his famous statement 'form follows function' gives priority to the third layer before the fourth layer. Today, on the contrary, the waging debates about environmentally friendly or 'green' architecture very often focus on the issue of energy, "a tendency to give top priority to the second layer", while ignoring the similar importance of the other three layers. "However, properly speaking, sustainable design should involve all four layers", as Namba pointed out.

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Next I'll show a short comparative analysis using the 'Four Layers of Architecture' framework, of traditional Oriental *mashrabiya* with two contemporary architectures, that translate the visual pattern of the local traditional craft into a design approach for a cultural distinctive adaptation of a modern technology.

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A short explanation of the four layers …

Even though the aspect of culture is not explicitly mentioned in either of the layers nor any of

the examples, it is inherently present in all of them. Architecture itself is an essence of culture, the cultural process of inhabitation.

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> *"At its highest level of significance, architecture is the fusion of culture and the need for enclosure made material in physical form; it is the meeting point of the need to build and the innate urge to communicate."*

If culture is so essentially important for architecture, the same should be true for sustainability. Even though culture is often not explicitly mentioned when speaking about sustainability, distinctive cultural approaches are essential for local and global sustainability. It is one of the most important keys for achieving the sustainability objective.

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Section 3. Light and Shadow – Nuances of Depth

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> *"In the thousands of years since he learnt to build, man has had to try to meet two particular, and often conflicting needs: on the one hand, the need to create enclosure for shelter, protection and privacy; on the other, the need to transmit light to provide illumination and view."*

The different regional and cultural perception of light and shadow has been recognised in the architectural debate. But light is more than the presence of it, and shadow more than its absence. The manifold nuances and meanings of shadow were beautifully described by Tanizaki in his book 'In Praise of Shadows'.

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> *"And so it has come to be that the beauty of a Japanese room depends on a variation of shadows, heavy shadows against light shadows - it has nothing else."*

From whatever side the issue of light and shadow is approached, important are not the ends, but the superimpositions that occur on the path towards each other, where the dichotomy essentially merges. Neither of them is eradicated, both are present. However, the cultural difference of the starting point can be traced easily.

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An example may be the Gothic stained window in comparison to the Arabic *mashrabiya*. The feature of the Gothic mosaic glazing is coloured light entering the nave of a church, its material expression is the translucent, colourfully stained glass. The feature of *mashrabiya* is shaded privacy, its material expression the wooden latticework. The difference of focus can be seen not only in the dualism of light and shadow, but in the attention of the craftsman, on the light transmitting material versus the shading material. What both approaches have in common are the variations of gradation.

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> *"The theme of light […], the blurring of contours, the superimpositions, in reverberations and reflections and shadows."*

The contemporary architectural output and the materialisation of light/shadow gradations within the layers of the building skin were analysed by Beccu and Paris, who call it a "new" opaqueness, a paradoxical *"accumulation of different kinds of transparencies".* What had been a clear composition of opaque and subordinated transparent areas during the European Renaissance turns into an ambiguous playground of *"infinite variations in its degrees of transparency"*. The true newness may not be so much the layering of the façade itself, but the eventual consideration of light as a form of energy, that has multiple spectra and can be preserved, dispersed, transformed, temporarily stored and inversely distributed during night time. With the help of photovoltaic devices, natural and artificial light respond in a newly found dual, dialectic relationship. Where, seen from the outside during daytime, a darker interior appears flat, this changes dramatically when the inside is illuminated. The degrees of transparency are enriched with spatial degrees of depth. However, what appears so novel when seen from the point of light, was already described by Tanizaki from the point of shadows in 1933.

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Section 4. Patterns, Parametricism, Performance

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> *" [Patterns] have been covering architectural surfaces since time immemorial, in the same way that they have been spread all over manmade objects."*

Patterns have always been present in the architectural debates. In his 'De Re Aedificatoria', Leon Battista Alberti, an architect and polymath of the European Renaissance, defined the patterns as the final component added to the volumes for producing beauty. In his book VI, architecture is defined as a process which starts from the naked volumes of the building, passes through the structures, and ends with the addition of the ornaments. Modernist architecture banned the use of any type of decoration, but today thanks to the advent of new technologies and design tools (such as parametric design), patterns have become once again central in the architectural debate.

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> *" Patterns provide architects with a device to connect apparently incongruent categories and synthesize a multitude of performances, project requirements and informational types in a perception-based medium."*

Patterns have served different purposes, and what interests us are their flexibility and high degree of adaptation. When used along parametric software, patterns are similar to seeds. They are to be seen not just as form, but as a generator (and problem solver) of performances.

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> *"The introduction of different surface effects, like different material textures, had already*

happened within the later phases of Modernism, but artificial, quasi-graphic techniques of surface treatment and surface patterning were now being deployed. […] Parametricism transforms this technique of parametric pattern design into a new and powerful register of articulation."

While architecture during the 20th century focused on function and form, the current architectural debate is dealing more with relationships, boundaries and energies. In this regard, parametric photovoltaic patterns have the poetic and pertinent potential to precisely promote performance, or in short: patterns promote performance.

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Section 5. Low-res – Pixel and Solar Cell

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From the manifold pattern revealing or generating algorithms we want to focus on low-res strategies. Low-res, or low resolution, usually describes the insufficient amount of a pixellated screen or image, where instead of a smooth gradation of colours or levels of brightness, the individual pixels can be distinguished, thus revealing a "digital" origin. In the world of computers, screens and digital images or films, low-res has been seen equal or near to bad quality. In the field of product design, the computer derived pixel art and architecture, however, it is seen as an inspirational approach for design and pattern generation. The appearance of façades or roofs as made up of smaller units is in itself nothing new to architecture. In fact, until the invention of monolithic concrete structures and surfaces, it was the only way to build, like bricks for walls, tiles for roofs and floors, stained glass pieces for windows of Gothic cathedrals, wooden pieces for *mashrabiyas*, etc.

So if it is nothing new, what makes it so compelling? Maybe the answer was given by Bullivant analysing the design approach of Ron Arad:

"[L]ow-res tactics in order to achieve appropriate, affordable, as well as poetic and more subliminal, effects, harnessing emotion rather than technology. At the same time, these tactics are programmed to be adjustable."

Next I'm going to show some examples of low-res architectural façades.

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The **Torre Agbar by Ateliers Jean Novel in Barcelona, Spain, completed 2005** has a multi-layered, pixel-like patterned façade. Some of these square pixels are opaque and coloured in a gradation from red at the bottom to blue at the top, some are openings that randomly perforate the load bearing shell. Some openings have coloured glass windows, others have clear glass. On the outside an enveloping layer of tilted louvres. During the day, the sunlight dances along the curved façade, and vibrates between and along the transparent louvres. It is the geyser Jean Novel is speaking of, a geyser of colour and reflections. During the evening and night, the building turns, illuminated by artist Yann Kersale, into a geyser of pulsating light and illusion.

"The surface of the building evokes water: smooth and continuous, shimmering and transparent, its materials reveal themselves in nuanced shades of color and light."

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The **GreenPix - Zero Energy Media Wall by Simone Giostra & Partners in Beijing, China, completed 2008** is an illuminated and mediated façade with integrated photovoltaic system. At daylight the façade generates energy with the help of three differently dense populated PV laminates, that are arranged in a compositional template reminiscent to *“seascapes as an example of an ever-changing visual experience”*. During daytime the reflections on the bumpy façade. During the dark hours the façade changes into a huge video screen, while using the during daylight generated energy, each laminate becomes one pixel for low-res video animations.

The two examples feature **illuminated and mediated** façades, that play with the reference to digital screens, low-res occurs in different scales due to the comparatively large size of the building.

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The **Santa Caterina Market renovation by Enric Miralles and Benedetta Tagliabue of EMBT in Barcelona, Spain, completed 1997** features a fluid, wavy, undulating roof covered with multicoloured ceramic tiles. Each hexagonal tile is combined in groups of 37 pieces to form a larger hexagon and to finally generate a tetris like pattern and collage, intended to *"reflect the polychrome art nouveau facades of the merchants' mansions and the public buildings those merchants sponsored"* .

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The **Technorama Façade by artist Ned Kahn in Winterthur, Switzerland, completed 2002** is formed by an even grid of thousands of movable aluminium panels, but the slightest breeze excites them to flutter and *“reveal the complex patterns of turbulence in the wind“* (Kahn, undated), a huge real time animation of the natural flow of wind energy translated into reflections and reverberations.

The last two examples feature **fabric surfaces**, either static or dynamic, that take reference to textiles and drapery folds. Here low-res is similar either to weaving as a structuring principle, or to dying and printing as a subordinate, overlaid principle. The following two examples feature **tectonic surfaces,** where low-res is the major structuring principle, with similarities to grains or structures in natural materials, that are intentionally exposed.

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The **Museum of Kanayama Castle Ruin by Kengo Kuma & Associates in Ota, Gunma prefecture, Japan, completed 2009** has a wall cladding made of thin rectangular stone slabs. The pattern is simple at first, but manifold when indulging in the building's deeper composition. Kengo Kuma generally operates with an approach fully without the computer derived, digital reference to pixels. He calls it *“particlization”, “apertures”,* and more recently *“gaps”*, and his modus operandi yields results, that are more affine to the pre-digital age and low-tech architecture.

> *“[...] by reverting to an even more primitive condition, to search for possibilities in an area that can only be resolved by a new, contemporary technology.”*

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And last but not least in this short catwalk of contemporary architectures ….

The **Hotel Industrial by Emmanuel Saadi Architecte, Jean-Louis Rey and François da Silva in Paris, France, completed 2008** is a renovation project, where windows were replaced with light-transmissive PV laminates. Pixelisation is used purely in its original, computer graphics derived sense, simply to alter a photography of limestone, the building's original cladding material, into a low-res image of positive and negative pixels. But instead of designing the material, the approach is turned upside down by alloting gaps for daylight to penetrate between opaque cells, to leack into the architectural volume. By night the play is reversed by spilling light into the street and joining the galanty show of the urban nightlife.

From these six examples, two feature integrated photovoltaic solar cells, the GreenPix - Zero Energy Media Wall by Simone Giostra & Partners and the Hotel Industrial by Emmanuel Saadi Architects have.

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Section 6. Case studies – Japanese traditional patterns as an inspiration for BIPV

What we have described in the previous four chapters, was the starting point for an investigative approach into applying the inventory of local cultural heritage as an inspiration for technological innovation. The following case study translates the spirit of traditional Japanese pattern into a contemporary design and pattern generating approach, bridging global technology with local culture.

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Light-transmissive photovoltaic (PV) laminates provided the technological test bed and Japanese traditional family crests were the cultural ingredient for this case study. The aim was to improve the versatility of light-transmissive PV panels used for architectural integration into building skins (BIPV).

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Even though PV is in general highly appreciated to contribute positively to a building's energy requirement in a sustainable manner, their actual use and integration into the building skin is lacking far behind their full potential.

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From a cultural point of view this is a matter of acceptance of a product appreciated for its technology, but not its appearance. One of the main reasons given, is that the standard products offered by the PV industry are regarded as insufficient to pleasantly merge the technological product with the demands of contemporary architectural design, thus rendering the appearance as 'added' instead of 'integrated'. In section 2 an example was given, that with the help of cultural referencing public acceptance can be achieved.

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PV technology nowadays can be separated into two major groups with differing material and visual attributes, the first group of crystalline silicon technology and the second group of thin-film technology.

Crystalline silicon PV technology is characterised by distinctive square, semi-square or round solar cells with 100, 125 or 156 mm edge length or diameter, who are additively tiled and laminated between sheets of glass or film to cover larger areas. With this kind of PV panels translucency is achieved by spacing the opaque crystalline solar cells, so that light can penetrate through the resulting gaps. Such panels are often called 'light-through' due to the remaining view obstructions.

The second group of **thin-film PV technology** on the contrary are monolithic PV sheets of manufacturer dependent and varying, but usually much larger size than crystalline silicon cells. Transparency is achieved by laser scribing a light-transmitting pattern of thin lines or tiny holes, a subtractive process. As this pattern yields a much finer, much more uniform transparency, such PV panels are called 'see-through' and have an appearance similar to tinted glass.

Our case studies focus on crystalline silicon cells for two reasons: (a) the manufacturer independent standardisation of the solar cell, which allows for widespread utilisation of the design proposals; and (b) the affinity of the additive tiling of solar cells to contemporary low-res strategies, as described in section 5. In the context of other materials low-res strategies are often employed as an organisational and pattern generating principle, but in terms of crystalline silicon cells it is an inherent quality. Here the smallest 'pixel' or 'particle' is equivalent with a single square, semi-square or round solar cell.

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For this study, kamon or traditional Japanese family crests were chosen as source of inspiration. Kamon depict plants, animals, natural or man-made objects. Some are very figurative, others are more abstract, but most inhere certain geometric qualities, and despite being monochrome exhibit a layered depth. We selected kamon, that are composed of square, rectangular or linear elements, which can be easily translated into single or groups of photovoltaic solar cells. Strong linear arrangement of PV cells is one of the requirements for an automated manufacturing process. Thus the selected kamon were applied to generate alternative light-transmitting PV patterns.

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This figure shows the layered structure of a light-transmissive PV laminate with the addition of a semi-transparent print on either side of the inner layer. This feature is a common option for glazings, but hardly explored in the application of light-transmissive PV. It also shows the two layers, solar cell layer and print layer, of which the final pattern will be composed.

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Finally, four exemplary case studies are illustrated, showing the source of inspiration, the translation into two layers, and a rendered image of a possible façade application seen from inside the building.

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Section 7. Conclusion

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This paper points to the importance of implementing into contemporary design not only present technologies, but also cultural uniqueness. It must be noted, that this is not an attempt of bringing traditional icons without thought into the context of modern design, but to highlight the importance of cultural adaptation of technology. Careful consideration must be taken to not cheapen the value of traditions.

Our case studies are an attempt to make clear that such traditional values combined with new digital technologies is not incompatible, as demonstrated in the case studies presented here. On the contrary, the use of Japanese traditional patterns as an inspiration for BIPV proves to be successful in the reinterpretation of the long established tradition and aesthetic of Japanese pattern design. Japanese sensibility retains its unique character even when it is used along with new technologies.

> *“ Japanese architecture is a treasure trove of boundary techniques. […] Diverse screens (such as louvers and [curtains]) and intermediate domains (such as verandas, corridors and eaves) are gaining attention once more as devices for connecting the environment to buildings.”*

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As Arad observes, design has always evolved alongside technology, a mutually beneficial relationship. Thanks to the use of parametric design software, we were able to edit, and use the traditional aspects pertinent to Japanese patterns and transform them into contemporary possibilities of what a BIPV product might look like. Now it is the task for the PV industry to incorporate the demand for custom designs into their production processes.

> *“This is not a dream, because technology plus poetry equals architecture […]. All architects […] have to do is make it happen.”*

To reflect once more on Cedric Price and his famous statement. Technology may provide answers, but as little as technology is a goal in itself, neither is sustainability.
Both are *“a constraint on the achievement of other goals“*.

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Thank you very much for your kind attention.