FROM STATIC TO KINETIC

The potential of kinetic façades in care-hotels

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Abstract

Architecture has typically resisted kinetics. Our buildings are static, surrounded by a very dynamic and ever changing environment. Buildings could respond to these fluctuations using kinetics, a responsive façade. There are not many completed architectural designs with a kinetic façade to criticize and to learn from, but they have a lot of potential. Integrating the kinetic façade in a climatic system could result in a more efficient and sustainable energy system and more pleasant internal climates in for instance care hotels. The resulting architecture could be helpful in creating a Healing Environment, to ensure the wellbeing of the patients and other occupants of a care hotel. The focus in this research is therefore: how can kinetic façades be valuable for a care hotel in the Netherlands? This main focus is addressed by analysing projects using kinetics in the façades, following the examples of movements nature by bio-inspired design, and defining what kinetics are most suitable for creating a Healing Environment in a care hotel. Kinetic façades that are integrated in the climate system of a building, respond to the sun, have to opportunity of keeping the user in the loop and create a beautiful silent poetic ensemble by simple and clean detailed movements are most valuable for a care hotel.

Keywords responsive façade – kinetics - sustainable energy system – Healing Environment – bio-inspired design
Introduction

‘Architecture has typically resisted kinetics’, states Jules Moloney (2011, p.3), Associate Professor in Interdisciplinary Digital Design, in his book on kinetics for architectural façades. I think he is right. Technology and innovation always seems far ahead of what is applied and designed in architecture. The same holds for the techniques that make architectural adjustments to the continuously changing environment possible. The most obvious reason for this is that new technologies are expensive. Therefore, kinetic façades are mostly used for iconic buildings, by an initiator who primarily wants to show that business is going well. The Al Bahar towers in Abu Dhabi are an example of this phenomenon. The result is a very expensive but aesthetically interesting architecture, where in case of kinetic applications; the movement of architectural elements creates a poetic ensemble.

Nevertheless, kinetics in architecture has a lot of potential as it could help create a positive effect on the internal climate by – either actively or passively - reacting on changes in the direct environment of the building. The façade forms the zone of the building that both protects the inside of a building from the outside, as a shelter, and at the same time mediates interaction between the two. Both internally and externally there are a lot of elements that change continuously. Static buildings are using a large amount of energy in order to compensate for all these fluctuations in the surroundings. Air-conditioning, ventilation systems, heating- and cooling systems, lighting; all need a lot of energy in order to regulate the intern climate of a building. The façade should therefore be a very dynamic part of a building in order to facilitate in the best interaction with these elements.

Although the technique used for kinetic façades is not as efficient or reliable yet, the concept seems promising. It could for instance be applied in façades of buildings with a care-function, where a “Healing Environment” (Mens, 2009) should be created for both the patients as for the people who work there. In the case of a care-hotel, a very specific internal climate is needed to make all the patients feel comfortable. ‘Comfort defines the technical quality of a building or building component in terms of air, radiation, noise, temperature as well as humidity’ (Knaack, Klein, Bilow & Techen, 2011, p. 49). A care-hotel houses both very private and public functions, which leads to a very wide range of demands of internal climates. A clear differentiation should be made in the type of climate and the regulation of more public program compared to the more private program. Because the users of a care-hotel are spending most of the time inside of their room, i.e. trying to recover from medical surgery, it is important that the climate of this room is individually adjustable to make them at best comfort, whereas in the rather public zones of the building, a more average internal climate can be maintained. An area that forms a transition zone between inside and outside – an atrium for example - could be used as a buffer zone. This way, sudden fluctuations in weather conditions or demands can be evened out, in order to keep the internal climate as steady as possible.

Kinetic façades could be a means to create the differentiations in the internal climate for the individual spaces, and could also help keeping the internal climate of the more public program balanced. They have a great potential when they are an integrated part of an architectural – climatic - design.
The main focus of this essay: ‘How can kinetic façades be valuable for a care hotel in the Netherlands’, will be appointed through three sub-questions that will define the scope of this research:

I - What type of kinetics in the architectural façade are the most effective and durable?
II - How does nature react on continuous changes in the environment by movement, and can we use these principles for bio-inspired design façades?
III - What type of kinetics is best to apply in care hotels in the Netherlands in order to achieve a Healing Environment?

First the methods that were used to find answers to these different sub-questions are addressed. The answers and findings to these sub-questions will be discussed separately in the results. Followed by a conclusion and discussion in which a probable answer to the main focus of this paper is formulated and discussed.

**Method**

‘The lack of content and the step outside traditions of static form provide a challenge for this new field of design research, as there is no coherent body of theory to reference, nor are there sufficient designs to critique.’ (Moloney, 2011, p.3) Nevertheless, this research was started by looking up as many completed and well documented projects in which kinetic façades are applied as possible. By doing this I wanted to gain more insight in what is already done. Subsequently an overview is made of all these projects – a total of 32 – to make it easier to compare them afterwards (appendix II). This overview gives insight in what ways kinetic façades are already applied in terms of what elements they respond to, the scale of the moving elements and the type of movement. Furthermore, the level of integration in the climatic system will be determined. To get better insight in a glance, and make it easier to compare the projects, A set of symbols is composed that communicates the elements that characterise the façade of the project.

Furthermore six categories are determined to categorize all the projects. Each façade is activated by certain elements that it responds to (1), the type of movement that follows could be either active or passive (2), and also the size of the moving elements differs per project (3). The way of moving (4) is based on the four basic types of movement which are explored further in the results. A more explicit categorization is made of movements for the projects in the overview in order to be more specific. Whether the façade is integrated in a climate control system or not (5) has influence on the effectiveness of the façade in terms of internal energy regulations. Finally, a differentiation is made in façades that are applied in new designs, or façades that are added to an existing building in terms of renewal of these buildings (6). As an additional part to the 32 projects, 8 concepts of movements in nature are examined. These are concepts of surfaces that have a smart way of functioning by responding to elements in their environment through movement. They could serve as a model for a bio-inspired architectural kinetic façade design concept.
To get to the conclusion for the main focus of this project the three sub-questions will be addressed individually. First I will focus on the effectiveness and durability of kinetic façades. Then examples from nature are explored, in the context of biomimicry. Thirdly, the climatic needs of care-hotels and how these can be turned into a Healing Environment is addressed. Answers to these sub-questions are found by analysing the reference projects, literature studies and research by design. Finally, the conclusions to these three sub-questions and the reference projects from the appendix will be interpreted and combined to conclusion on the main focus of this research. This conclusion will also be discussed in the same section.

Results

In order to be able to give a final result of the main focus of this paper, first the three sub-questions will be addressed in this section. Since a lot of the results are linked to data I gained from the reference projects I added them in the reference project overview. Notice that there are both kinetic (K) and media (M) façades explored in this overview of projects. The difference between the two is that a kinetic façade moves mostly to regulate the internal climate, whereas A media façade uses light to provide its surrounding with information. Both could also be applied for artistic reasons; to tell a story by poetic movement of changing physical elements and lights.

I – What type of kinetics in the architectural façade are the most effective and durable?

Movement and continuous change of a building’s surface could be something intriguing to look at. When designed well, kinetic façades are a piece of artwork. They tell the story of dynamics in a poetic sense. But on top of their factor of beautification, users of a building could also take advantage of the movements in terms of comfort and energy efficiency when this kinetic façade starts to adjust to its direct environment.

‘Although the form and the movement is in itself simple, it appears complex and unfathomable. Therein lies its poetry.’

- (Schumacher, 2010, p.8)

The essence of kinetic façades is their dynamism (Moloney, 2009). They are in a constant state of change. The outcome of a design for a kinetic façade is therefore never a singular form but a range of forms that are varied caused by an input that generates movement. To get a grip on this movement it can be categorised in different types. At the very base of movement of architectural elements, there are two basic types distinguishable: translation and rotation(Schumacher et all., 2010, p.45). According to Jules Moloney (2011), scaling and material deformation should be added to these two basic movement
types. Although these last two seem to appear less often, probably because of their complexity. A combination of two or more of these four basic typologies results in a more complex form of motion, (appendix I). A range of often appearing movements in architectural façades of the reference projects is listed in the symbol clarification at the start of the reference project list (appendix II).

This idea of adjustment to a changing environment in an optimum way is however not innovative. About 100 years ago, around the 1890’s until the 1930’s, we already were able to tune buildings to respond to seasonal climatic conditions, it is in fact an old strategy. Our buildings were perfected to seasonal climatic conditions. However, designers have become lazy. The mass adoption of air-conditioning and similar systems made us forget how to build in a responsive way (Linn & Fortmeyer, 2012).

The oil crisis in the 1970’s was the start of a turning point in this “laziness”. The eyes of society were opened; the resources of our earth are not endless and we have to act more precautionary and conscious. It started a tendency of sustainable design, not only in the architectural sector. But because of high costs and the large amount of building stock and the amount of effort it takes to change a way of doing in society, we are still far from having a sustainable one. ‘The global energy demand can be attributed to three main areas: buildings, transport and industry. The first two categories are responsible for an estimated 75% of the worldwide energy demand and can be directly influenced through architecture and urban design.’ (Cody, 2010, p.124) We need to look for solutions in order to make the built environment more self-sustainable. ‘By utilizing the building fabric itself (the ‘skin’), artificial heating, cooling, lighting and other energy importing systems can be minimized, or avoided altogether. Ideally, a building is a power station in its own right’ (Wigginton, 2002, p.14).

The skin of the built environment should be able to adapt, react, and respond to changes in the environment. We have to move from a static architecture towards an architecture that is characterized by kinetics. Based on the investigation of the 32 reference projects, there are three basic levels of kinetic façades distinguishable:

- Kinetic façades that only have an aesthetic purpose, which could be seen only as pieces of art.
- Kinetic façades that help reduce the energy demand of a building – either actively or passively.
- Kinetic façades that both help reduce the energy demand of a building and generate energy.

The last two gradients of kinetic façades are better integrated façades in terms of a climatic regulation system and are therefore of most interest for this research. They do not just move in order to impress people on aesthetic grounds; they really add value to the climatic system of the design either by lowering the energy demand for the climate regulation or by even generating energy for the system.

Furthermore the relation of movement, energy and architecture can be examined. Four levels of ways that the three key elements could relate to each other are distinguished. The first level is buildings that contain integrated energy supply systems all having something to do with movement, i.e. wind turbines. These are singular systems that are added to a building and not integrated in the architectural form. The second level contains technical installations that are ultimately responsible for
energy consumption in buildings such as heating, cooling, ventilation and lighting systems. For some of these, movement is more evident than others. Furthermore there are movements that improve energy efficiency of a building and offer a number of interesting architectural possibilities, i.e. exploit movement of earth around the sun. These form the third level and can result in low energy designs. Finally there is a level of moveable parts of a building which can also increase its efficiency (Cody, 2010). The aim that I have for kinetic façades for a care-hotel is that they can be ascribed to either the third and or fourth level. These two levels will reduce the amount of energy that is needed for the movements belonging to level 2. Furthermore, I think that moving systems integrated in the design instead of added as is the case in the first level, will lead to a less valuable design when it comes to the architectural form. The projects that are analysed in the overview can therefore also be ascribed to level 3 and/or 4.

Fig. 1. Four levels of relations of movement, energy and architecture. Level 1: buildings that contain integrated energy supply systems all having something to do with movement. Level 2: technical installations that are ultimately responsible for energy consumption in buildings. Level 3: movements that improve energy efficiency of a building. Level 4: moveable parts of a building which can also increase its efficiency (adapted from: Cody, 2010).

Most kinetic façades addressed in the overview of reference projects react on sunlight (table 1). The projects that respond to wind or temperature seem to most of the time do this in a combination with response to the sun. Of all the seven elements a façade could respond to, the element sunlight is most effective. ‘The sun offers great potential in terms of passive and active gains for heat and electricity. However it can also be detrimental to internal comfort conditions, and as such it is often necessary to mitigate against its harmful effects which include glare and radiant overheating.’ (Wigginton & Harris, 2002, p.32) Kinetic elements responding to sunlight could therefore be used both for protection against glare and heat load, and regulation of the right amount of daylight inside the building. But also to generate energy possibly in combination with photovoltaic (PV) cells or solar collectors.

Most systems that react on wind in the overview of reference projects do this for aesthetical reasons or in order to protect the mechanism from being overloaded by wind forces. The Quadracci Pavillion in Milwaukee (appendix II) responds to wind to protect the kinetic wings form an overload for instance. Generally only a handful of projects respond to wind in order to influence the ventilation in a building or in order to generate energy from moving air. To be efficient a constant wind speed of about 8 m/s is
needed (Bansal, Bhatti & Kothari, 2002). In the Netherlands the average wind speed is however about 5.5 m/s (KNMI, 2015) and only seldom about 8 m/s, which is even then most of the time not the case at ground levels in the cities. However, the higher the speed, the more energy can be generated. It is a curve with a quadratic correlation. (Bansal et al., 2015). Projects that are built in unobstructed areas with a considerable amount of continuous wind may have the opportunity to use wind as an energy generator, i.e. the windmills that are located in the see or on agricultural land.

![Diagram]

Table 1 - Amount of references that react on or adapt to a certain element. Some references contain façades that react on more than one element. Most façades respond to the sun, or a combination of 2 or more elements. Façades responding to data are most of the time media façades.

A kinetic façade can only be efficient as long as the system of functions. How durable a system is, is influenced by the type of material, the cleanliness of the detailing of all the moving components and most importantly the amount moving elements. What is most important about the material is that it is resilient to all weather conditions. Humidity, sunlight, temperature differences are all factors that influence the quality and properties of a material. Furthermore the construction it should be able to carry the dynamic loads of the kinetic elements also caused by weather conditions such as wind forces or water loads.

Reducing the amount of junctions also has a positive effect on the durability of the system but also on the costs needed for realising the façade. The more difficult the movement, the more sensitive it is to failure and intensive maintenance. However, the more axes are added to a movement, the more artistic and special they will become. These are the façades that are really booming, standing out, iconic, but also need a high end construction and technique that supports the movements. There are also kinetic façades that are built up from movement around just one or two axes. Because these movements are in essence rather simple, they are more likely to be more durable. In figure 2, three examples of kinetic façades are shown.
The Al Bahar Towers (appendix II) have a very blooming and outstanding kinetic façade, but are, as turned out in practice, very sensitive to technical failure. The Sliding House and the façade of Café Open (appendix II) have a simpler kinetic façade, but turned out to work well in once the project was finished. And as arguable as this statement is; both the simpler façades do have an outstanding architectural effect.

As is elaborated in the beginning of this section, there are a wide range of movement types. In the overview of references 10 types or combinations of these types were identified. There is a correlation noticeable in the type of movement that is used, and the elements that the façades respond to. As is visible in table 2, the movement types of flaps, folding, rotation and sliding are mostly used. This phenomenon applies in general but also in order to respond to the sun. Also LEDs are a type that is used a lot, but react mostly on digital data and are often applied in Media façades.

<table>
<thead>
<tr>
<th>Reaction/Adapt to</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<tr>
<td>Sun</td>
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<td>2</td>
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<tr>
<td>Rotation</td>
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<tr>
<td>Sliding</td>
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<td>Flaps</td>
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<tr>
<td>Folding</td>
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<tr>
<td>Way of moving</td>
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Table 2. Correlation of elements and type of movement. The sun is most responded to by flaps, folding, sliding and rotation or a combination of these types. Media façades using only data are mostly kinetic in the form of using LEDs.
In the caring sector there is relatively less budget available for aesthetics and architecture. Simple kinetics will be more convenient in reducing the climate regulation demands of a building. Movements along one or two axes are more reserved in what they communicate to the environment; they create a simple scale of effect. The aim for kinetics in a care hotel is focussed on silent movement. The building is changed every time you pass by, but you do not really notice obvious movement all the time. It is more about the poetics of movement, the quiet and peacefulness.

What can be concluded from this section is that façades that have the highest potential of improving efficiency are the ones in level 3 or 4 (fig. 1.). These façades are more integrated in the architectural design and the climate system. It is furthermore very efficient to respond to the sun. Both by blocking unwanted energy (heat and light), but also by providing the intern climate with right amount of light and radiation. In addition, sunlight has the highest efficiency when it comes to generating energy (PV-cells / solar heat). Of which it is doubtful whether the façade is the best location for placing these systems, since the roof provides for better placement of these items. Durability is best accounted for when a kinetic façade is build up from elements that move one or two axes. Flaps, folding, rotation and sliding are mostly used for responding to the sun by movements as seen in the overview of reference projects (appendix II). Detailing should be as clean as possible to make them less subjective to failure and to make maintenance less complex and needed less frequently.

II – How do biological “façades” react on continuous changes in the environment, and can we use these principles for bio-inspired design façades?

Most buildings are static, while everything around these static walls is changing all the time. Think about temperature, daylight, wind, rain, tides. What all these changing factors seem to have in common is that they tend to reoccur at regular intervals. Seasons and all their characteristics are a coming and going in regular, cyclic and self-contained processes within the larger order of things (Schumacher, 2010). Nature can be beautiful, but also dangerous. Humans like to regulate things in order to control it. This is what we also do in our built environment. We create ordered gardens where danger is not present anymore. We can feel safe and at ease in our superficially created piece of nature. Nevertheless, the dangerous side of nature is always able to overrule our control, i.e. with extreme weather conditions. The built environment also disturbs the closed cycles of nature by all the exhaust is generates, raw materials that are extracted. We are polluting our own world. It is essential that we change our way of doing and try to close the cycles of nature again.

In nature, the species that are adapted the best to their environment, meaning the ones that need less energy compared to other species or fellow species, are more likely to survive. Furthermore, species that are able to eradicate “errors” in the cyclic processes of nature by adapting to them will continue to exist. It is the principle of natural selection, as we have learned from Charles Darwin. Why does this rule of natural selection not apply to our built environment? Buildings that adapt the best to changes in their micro environment need the least energy in order to maintain a comfortable internal climate, and would thereby be best resistant to high energy costs, or in the long term vacancy.
The consequence is that these building are more likely to “survive”. Furthermore, these buildings help saving the environment. As Walter Kroner, energy conscious architect and professor of architecture at Rensselaer Polytechnic Institute in Troy, NY, said: The use of intelligent design is in architecture a striving to have our buildings in harmony with nature. It is a means to project its qualities, and to recognize its dynamic and unpredictable qualities by responding to them, whether actively or passively. (Kroner, 1997)

We could consider the building envelope, or the façade as the buildings’ “skin”. In nature, “skins” perform a range of different functions to respond to continuously changing conditions and are self-regulating (appendix VI). The way “skins” operate and move could be used as an inspiration for both form and function in design of the architectural skin. Form imitation is the most straightforward because it relates directly to the appearance and movement principles of a biological system or organism. Function tends to be more concerned with what the façade does rather than what it looks like and is more inspired by what a biological organism or mechanism does. (Loonen, 2015)

The way sunflowers move during the day is not noticeable at once. Their flower heads follow the path of the sun caused by irregular growth. This way the seeds capture as much sunlight as possible to improve their development and in order to stay dry. When solar panels would adapt the same movement principle, the efficiency of the panels would be higher compared to a static position during the day.

But there are more movement principles that can be adapted in architecture. The opening and closing of the façades used for regulating the amount of daylight, fresh air and regulation of temperature is all done by moving elements. ‘This requirement for a building to ‘open up’ or ‘close down’ has obvious relationships in the optical actions of the human eye, which we close when we wish to sleep and the iris of which ‘stops down’ the pupil automatically in bright light.’ (Wigginton, 2002, p.vii)

The movements of the concepts (appendix VI) have the same types of movement as are used in most of the reference projects (appendix II and table 2) the movement are as simple as possible and do not have more than two axes. Rotation, folding, sliding and flaps are movement types that, like it is often applied in buildings, also appear often in nature.

III – What type of kinetics is best to apply in care hotels in the Netherlands in order to achieve a Healing Environment?

A Healing Environment, it is a pretty modern term that is mostly used for functions in the health care sector. But is, in a broader sense of the term, applicable anywhere. A Healing Environment is essentially a summation of many individual and spacious aspects that together generate a feeling of wellbeing and stress reduction (Koppen, Vollmer & Schaaf, 2012). This is not only relevant for people to heal quicker, but also in order to keep them healthy. A Healing Environment is about a good air quality, good temperatures, sufficient daylight, but also the right spaces and furniture that make you
feel comfortable. The right use of colour, the use of indoor plants and having a view on nature also seem to have positive effects on the wellbeing of the users of a building (Mens, 2009). Especially in the health care sector, it might take away the clinical character of the building. The way a Healing Environment can be created is nevertheless very diverse, because of a difference in primary users that have different requirements.

‘The indoor climate demands strong personal manageable and users want to be able to regulate it themselves’ (Lieverse, 2009, p.65). Furthermore, a Healing Environment is only successful when factors from the environment are an integrated part of the design process from the start and in the end of the design itself (Koppen et al., 2012).

Users are not always aware of all the components of a climate system and how to use them properly in order to get the preferred internal climate and a better energy sufficiency. Therefore, a computer controlled system could take over this task.

When using an automated system that controls the kinetic façade and the regulation of the internal climate (fig. 3), it is, in providing for a Healing Environment, essential that the user stays in the loop of control. The human in the loop principle is basically giving the user the opportunity to intervene in the controlled computer steered system. In what part of the control system of the kinetics the user should be able to intervene depends on the amount of influence that you would want to have the user to have. If the user should be able to control the internal climate for a whole group of people, it would be more effective to let one user, who is in charge, intervene somewhere in the start of the control system. If the user should be able to just make some personal changes to the internal climate, it should be on a much smaller scale. The user is only able to control a very small part of the whole system.

Fig. 3. ‘Stage (1): Cladding component actuated by switch. Stage (0): Cladding components are connected to a sensor/actuator device and can adapt automatically to changes in environmental conditions. Stage (1): Similar to stage (0) but with a central control unit. Stages (2) and (3): The building façade consists of several small-scale cladding components, each of which is connected to a local sensor/actuator and can perform automated adaptation. There is communication between the components. In Stage (3), the introduction of a central computer enables the accumulation and processing of data to facilitate better adaption of the system over time.’ (Grobman & Yekutieli, 2013, p.1054) The red square shows where the user can intervene in the system. Size depending on the amount of influence a user can have.
A different program asks for different solutions. The type of internal climate that is really needed per type of program should be determined. Public spaces need enough light and fresh air, acoustics should be good, and when there are many people in a room, cooling is of importance. More private rooms need more heating, warm water, sufficient lightning and a temperature preferred by one or two persons. The internal climate of these rooms could relatively differ more from each other. The public program and the individual ones could be combined, i.e. warmth that is not needed in the public spaces could be transferred to the more private spaces. The kinetic façade can help facilitate in this.

The façade of the building is a very multifunctional part. Its aesthetics are the first thing when approaching a building. Form, materials and signs communicate what kind of function can be found inside the building. Furthermore, the façade says a lot about the climate that the building is located in. At least, the designers had to have the intention to react as smart as possible to the characteristic climatic elements of the location. Even though this is a matter of taste, most intelligent façades are not a good aesthetical example. They are designed more for functional aims than for aesthetics. Kinetic façades are a means to combine the best of both worlds.

There is a correlation between the type of climate and the type of kinetic façade. In case of a hot climate, all the kinetic façade does is practically to block the sunlight heat load. Because these hot climates are more predictable, the controlling system can be preconditioned more easily. At all times sun and heat must be kept out of the building as much as possible. In temperate climates the weather prognosis is less stable. The weather and the demand of the users fluctuate a lot. Climates where weather varies from day to day should be responding more to these changes. This results in a different system including a larger range of different components that regulate the internal climate.

The focus of this research is on the value of kinetic façades for a care hotel in the Netherlands. Therefore, a selection of reference projects (appendix II) that all are located in an environment characterised by a temperate climate – CfB – (Peel, Finlayson& McMahon, 2007) is set up (appendix V). What can be concluded from this selection is that it is still very useful to respond to the sun. The pattern of the adaption is only less predictable compared to the pattern the façade will have when responding to the sun in a hot climate.

Materials, all components that form the internal climate of a building, use of color, amount of nature in and outside the building, the level of intervention caused by the principle of “human in the loop”. It are all factors that influence how a building is perceived and how it affects the wellbeing of the users. A Healing Environment is created by combining these factors to an optimum, depending on the wishes, demands and needs of the user.
Conclusion and Discussion

‘Architecture has typically resisted kinetics’. (Moloney, 2011, p.3) Although kinetics in architecture is not as efficient and reliable yet, the concept has potential. Kinetic façades could for instance be applied in buildings with a care-function to make them more energy efficient and to contribute to the realisation of a Healing Environment.

It is not possible to regulate the internal climate of a building by only using kinetic façades. Buildings that have kinetic façades that are not integrated in the climatic design are mostly used because of the aesthetics and the poetry of movement that they evoke. These designs can be seen more as a feature rather than a functional addition to the climatic regulation of a building. Kinetic façades that are integrated in the climate system are mostly computer controlled. In care hotels it is desirable for the user to be able to influence the internal climate by using the “human in the loop” principle.

Translation, Rotation, scaling and material deformation are the four basic types of movement. Because Scaling and material deformation are more complex they are not applied very often in architecture. Sliding, folding, rotation and flaps are mostly used. The designs might be inspired by nature since these specific movements seem to appear often nature too. Survival of the fittest is a rule in nature that should also be integrated in the system of our built environment. Buildings that are able to adapt best to their surroundings are more energy efficient and more in harmony with nature.

Kinetic façades responding to the sun, by sliding, folding, rotation or flaps are most applied and most effective. It creates the opportunity to both protect the environment from the harmful effects of sunlight and provide from all the good aspects. Responding to all other elements such as wind and temperature are additional chances and could best be done in combination with responding to sunlight.

Only a very small amount of the kinetic façades are designed to physically generate energy. It is difficult to generate energy and simultaneously have the optimum movement or position to do so. Other parts of the building might be more convenient for generating energy. Placing PV-cells on the roof of a building for instance is a lot more efficient because of the angle they are placed in and the amount of hours that the sun will touch upon the roof.

Many of the kinetic façades in the reference project overview (appendix II) that are realised are iconic. These projects are easier to find because they are well documented. This also reveals something about the costs of these façades. Booming kinetic façades, consisting of moving elements with many movement axes are added to the façades to turn them into an icon and are published. These façades mostly do not function properly in making the internal climate system more efficient, but are nevertheless a good investment as the company is known for their amazing buildings. Façades that are less spectacular in the way they move get less attention from the media. Nevertheless, simple kinetics are more durable due to cleanness of detailing and the little amount of movement axes they create a simple scale of effect.
In the caring sector there is relatively less budget available for aesthetics and architecture. Simple kinetics will be more convenient in reducing the climate regulation demands of a building. The building is changed every time you pass by, but obvious movements are not noticeable all the time. Silent kinetics is more about the poetics of movement, the quiet and peacefulness.

The purpose of applying kinetic façades in a care-hotel building design is to improve energy efficiency of the building while offering a number of interesting architectural possibilities. The façade could either increase the efficiency or even generate energy or heat for the building. Furthermore, it provides an intern climate that stimulates the wellbeing of the users. A kinetic façade that generates enough energy to serve the whole building is not realistic. But since every building needs a façade that regulates and protects against the differences in climate inside and outside the building why use it at its most. Especially since a kinetic façade simultaneously contributes to a beautiful and poetic ensemble.
Reference list


Appendix

I - Basic types of movement
II - 32 case studies of kinetics in architecture
III - Case studies located on a world map
IV - Case studies located on the map of Europe
V - Case studies that have a similar climate as the Netherlands
VI - 8 movement concepts form nature for bio-inspired design.
I - Basic types of movement

Rotation
Translation
Scaling
Material deformation


II - 32 case studies of kinetics in architecture
# Symbols

<table>
<thead>
<tr>
<th>Type of facade</th>
<th>Scale of kinetic element</th>
</tr>
</thead>
<tbody>
<tr>
<td>kinetic facade</td>
<td>the whole facade as one piece</td>
</tr>
<tr>
<td>media facade</td>
<td>parts or volumes in the facade</td>
</tr>
</tbody>
</table>

## Responds to / Activated by

- sunlight / daylight
- wind
- temperature
- (human) movement
- digital (or analog) data
- only on demand

## Way of moving

- flap
- fold
- rotate
- pivot
- slide
- expand and contract
- gather and release
- leds
- pneumatic or hydraulic
- seasonal greenery

## Type of activating movement (energywise)

- active activation
- passive activation
- generating energy in facade

## Building approach

- new building
- re-new of a building

## Integration

- System on its own
- Part of overarching system
The building is a showcase for sustainable development and urban renewal. Received a LEED Platinum certificate in May 2012. The building's bioclimatic, energy-efficient design features a 377 ft (115 m) tall solar chimney, a geo-thermal HVAC system using 280 five-inch tubes bored 380 feet into an underground aquifer, 100% fresh air (24 hours a day, year round, regardless of outside temperature) and a one-meter-wide double exterior wall (biodynamic double facade) with computer-controlled motorized vents that adjust the building's exterior skin throughout the day and evening. Together, the various elements of the design enable a 70% energy savings over a typical large office tower.
The overriding design motif applied to all the new buildings on the campus is the “shell – core” principle. There are two types of facade: One faces the central space, the other faces the exterior and is therefore responsible for the impact the buildings create in the surrounding area. The glass- roofed atrium is at the building’s centre. It rises over 10 storeys in height and is segmented by countless mezzanines and footbridges. Two monumental landscape windows act as delimiters on the north and south sides. The new, highly efficient sun protection system has a key role in the overall appearance. The circa 400,000 stainless steel lamellas are oriented in response to the location of the sun and enable light redirection without blocking the view.
Folding and sliding doors have been used to create an all-opening office façade. The building design changes its appearance and behaviour with the changing times of day and year. Key factors of this architecture are clarity, lightness, permeability, transparency, openness, and a consistent focus on the needs of the users. The inner space is closed by a thermally insulated folding glass door with wooden frames. A transparent slide-and-turn-system encircles the outside of the building. Both façade layers can be completely opened, thus allowing manual regulation of air supply: A completely closed façade offers maximum thermal insulation, with the outer skin functioning as solar air collector. By opening the inner facade, the users allow fresh pre-warmed air to flow into the building. The air-flow is supported by a natural updraft created in two atria. This showroom office is operated fully on renewable energy sources. Every single user is the operator of the building and responsible for his/her personal indoor work-climate.
The white panels function as sunscreens that are folding elements made of perforated aluminium. The panels are electrically driven. The facade panels can be adapted individually to changing conditions and needs, both automatically or manually. Of course they can also be controlled by optimising programs if users are not present in the rooms behind. Thus it is possible to realise these new transparent façades and yet still maintain a cosy atmosphere in the rooms. Furthermore the facade can be seen as an aesthetical gimmick. These façades change continuously; each day, each hour shows a new "face". The façade is turning into a dynamic sculpture.
The bird shaped entrance opens when the museum opens as well. The 27 m high steel and reinforced concrete construction contains the new entrance hall for the museum. The project responds to the culture of the lake: the sailboats, the weather, the sense of motion and change. If the wind speeds exceed 37 km/h, a computer controlled system intervenes and closes the wings automatically. The 36 steel elements vary in length from 8 to 32 m and take 3.5 minutes to open and close fully. Each rotating steel outrigger is linked to its neighbour by a distancing piece so that a fluid motion results.
Characteristic to this house is the wedge-shaped roof that extends about 4 m over the terrace. Both the material of the facade and the form refer to the wings of an airplane. Just like those wings some parts can move. This time the movement is not used to create a lift f.e. but to allow more light into the living room on the garden level below. The moving parts can rotate up to 60 degrees. The flaps are controlled using electrically-powered motor-driven telescopic rams. Grooved ball bearings take up the axial loads of the kinetic construction and stops in the fixed sections of the roof wedge which prevent the flaps from rotating freely.
Umbrellas that pop out of the building with a span of about 15m. Just like the Al Bahar towers the shape of the elements are based on the Arab Mashrabiya pattern. The umbrellas are retractable and will disappear in the space in between floors. Whether the facade really works or not, the umbrellas turn the building into a great iconography. Not only are the interiors of the towers shaded, the towers themselves also provide shadow for the buildings in the surrounding. At night the eastern facade turns into a media facade, when the LEDs that are integrated on the caps of the umbrellas on the whole surface turn on. From afar, the towers form a jumbo television screen, broadcasting the companies’ content to their environs in real-time.
The EWE arena has a large mobile sunscreen that slides along the facade, following the sun during the day. The construction travels along a stainless steel track mounted on the upper ring of the facade. The screen measures 36 × 7.60 m and is built up from 18 segments. Each segment has four photovoltaic modules. Each segment has one powered roller and one freewheeling roller. The upper ring of the facade supports the entire weight of the construction while the lower ring resists lateral wind loads. The sunscreen can travel 200 degrees around the perimeter of the building and consists of 200m² photovoltaic cells which generate 27200 kWh per year.

**Architect:** asp Architekten Stuttgart, Arat-Siegel-Schust  
**Year:** 2005  
**Function:** Sports arena  
**Surface:** 8500 m²  
**Type of response:** Active  
**Climate type:** temperate climate (Cfb)
RWTH Heizkraftwerk
Aachen
Germany

Architect: IP Arch
Year: 2010
Function: Educational spaces
Surface: 650 m²
Type of response: Active
Climate type: temperate climate (Cfb)

The media facade is characterised by a bright facade that is built up from horizontal extending aluminium strips that are placed in front of the steel volume. The strips differ in height, and seem to open in front of back lying windows. The strips function as a glare protection layer and are separated by a 3 cm wide gap, from where glows an orangered color at night. It is reminiscent to the period when the park of the building was still used as an energy generator. Today, the facade communicates the amount of energy used in the building. The more energy there is used, the brighter the orange-red lights will become. It is a metaphor for the former smoldering coal in that part of the building that was used to heat the entire building. Materials in the facade are metal, glass and aluminium.
Ziggodome
Amsterdam
Netherlands

Architect: Jan Benthem (Benthem Crouwel Architects), Job Schoën
Year: 2012
Function: Concert Hall
Surface: 49000 m²
Type of response: Active
Climate type: temperate climate (Cfb)

Since the Ziggodome does not need any daylight for its program, the facade could just be a closed box. To make the building stand out more, the facade is cladded with LEDs all around. From a close distance, the LEDs seem to be placed a great distance from each other. But from a larger distance the facade forms a large media facade that communicates upcoming shows etc. The building is visible from the highway as well and forms a good piece of an icon as well as a medium of advertisement. The facade of the Ziggodome is not typically a facade that moves in a kinetic way, but it does change in a visual way.
The sliding house consists of three volumes covered by a second 16 m long layer (sleeve) that envelopes the whole ensemble. The sleeve slides over a 33 m long rail, resting on 14 steel wheels powered by four 24V electric motors. Depending on the position of the mobile enclosure, the degree of openness or enclosure can be altered. When parked in one of the many other positions, a whole range of different spatial situations can be created. In summer, the sliding roof shades against the sun. In winter, its function is reversed: during the day it is retracted to allow passive solar gain in the glazed section, and returned at night to shield against heat loss. The motors can be powered by mains electricity or two 12V car batteries each, which in future will be charged by photovoltaic cells. The maximum speed of travel is 0.322 km/h. It takes 6 minutes to travel the entire distance.
The interior extends from the ground floor to the roof creating a sense of spaciousness within the small building. The first floor is conceived as a box inserted inside this space. When additional space is required, the bedroom can be extended outwards to project like a drawer some 2 m outside the box. A key-operated switch turns on two 360V electric motors, causing the drawer to travel along its axis on two racks for 3 mins. Automatic switches at the end of the rails shut off power. This way an indoor space becomes an outdoor space.

Architect: Seifert Stoeckmann
Year: 2005
Function: Dwelling / Residential
Surface: 24 m² (‘drawer part’)
Type of response: Active
Climate type: temperate climate (Cfb)

Living Room
Gelnhausen
Germany

Architect: Seifert Stoeckmann
Year: 2005
Function: Dwelling / Residential
Surface: 24 m² (‘drawer part’)
Type of response: Active
Climate type: temperate climate (Cfb)
At first glance the building looks closed and monolithic. But once the building is in use the volume changes markedly. The large gates open vertically upwards. The three rising sections are powered by three synchronously driven electric motors with cable winches that are concealed in an underfloor channel at the base of the gates. Also the shutters are able to open and close in order to regulate daylighting inside the building. The copper will over time change colour into green-blue, which is characteristic for copper.
The sunscreens placed in the facade have a thickness of 6 mm and allow a diffuse daylight to enter the building when the panels are closed. The panels are made of acrylic glass and both slide and fold to open and close. Furthermore a double layer is created that results in panels both folding towards to building and outwards. Altogether 18 different individually adjustable sections of the facade have been fitted with sunscreens, each with 25 elements. Half of the vertical posts are mobile and slide back and forth with the gliding rod. The other half remain stationary and are fixed to the guide rail.
The renewal of this building is characterised by the proposal of an intelligent facade coupled with an intelligent building. The open interior courtyard has turned into an atrium that serves as a buffer zone. The existing, defective external facade cladding was removed and replaced with new high-performance windows and 120mm of thermal insulation. To prevent too much solar gain in the summer, a modern interpretation of window shutters is applied. They are burglar proof, air permeable and also functions as an effective weather barrier. They are made of electropolished expanded metal sheeting with an embossed pattern, mounted on a tubular frame of extruded aluminium profiles. Due to location and orientation the shutters are mounted on all four sides of the building. A central control system adapt continuously, but individual users can override the system when desired.
Hotel Amstelkwartier is the first LEED platinum certified hotel of Europe. An integral sustainability is achieved by closing the cycles of energy, water, waste and materials. At the same time a ‘sense of place’ was an important goal. The core of the building holds all the facilities of the building, leaving the opportunity to gain as much daylight as possible in the spaces around it. Natural ventilation is possible on every floor (even 20th). The facade (insulated shutters) changes continuously under the influence of the hotel guest, the weather, time of the day and the season. This way the facade saves the largest amount of the energy need. The energy that is left is generated in the building itself. Grey water is used for toilet flushing, rainwater is used for the weeds on the roof, the hot-house absorbs CO2 from used air, and the warmth from the same air is re-used. Materials are recycled as much as possible, and are preferably coming from local suppliers and manufacturers.
Using a parametric description for the geometry of the actuated facade panels, the team was able to simulate their operation in response to sun exposure and changing incidence angles during the different days of the year. The screen operates as a curtain wall, sitting two meters outside the buildings' exterior on an independent frame. Each triangle is coated with fiberglass and programmed to respond to the movement of the sun as a way to reduce solar gain and glare. In the evening, all the screens will open, so that the glass facade becomes visible again and the building is able to cool down more easily. Driven by a linear actuator that will progressively open and close once per day in response to a pre-programmed sequence that has been calculated to prevent direct sunlight from striking the facade and to limit direct solar gain to a maximum of 400 watts per linear meter. In the end, the facade does not work properly in opening and closing.
The facade is an integrated part of the building and together, they create a unique and varying expression. Inside in the five floor high atrium, the displaced position of the staircases and access balconies creates a special dynamics where the triangular shape repeats its pattern in a continuous variety of positions up through the different floors. The solar shading system consists of approx. 1,600 triangular shutters of perforated steel. They are mounted on the façade in a way which allows them to adjust to the changing daylight and desired inflow of light. When the shutters are closed, they lie flat along the façade, while they protrude from the façade when half-open or entirely open and provide the building with a very expressive appearance. The solar shading system is fitted with sensors which continuously measure light and heat levels and regulate the shutters mechanically by means of a small motor.
Viewed from the exterior, the car park’s entire eastern side will appear to ripple fluidly as the wind activates 250,000 suspended aluminium panels. As it responds to the ever-changing patterns of the wind, the façade will create a direct interface between the built and natural environments. It is further embellished with rippling lines from the surface of the Brisbane River: a site-specific reference to the city’s most iconic natural feature. Inside the car park, intricate patterns of light and shadow will be projected onto the walls and floor as sunlight passes through the kinetic façade. The design also provides practical environmental benefits such as shade and natural ventilation for the interior.

Architect: Ned Kahn + UAP + Hassel Sidney
Year: 2012
Function: Car Park
Surface: x m² (facade 5000m²)
Type of response: Passive
Climate type: Humid subtropical climate (Cfa)
This element, composed of 122 aluminum tubes arrayed across the south facing façade, demonstrates wave action to students arriving at the facility. The tubes are magnetically coupled and held along a single pivot point on the building and when wind blows across the façade or when a student activates the element, each tube ripples as waves move across the face of the building. In this signature exhibit, themes of the Science Center - wave motion and propagation, gravity, resonance, and light - are expressed in action. Visitors walk under the magnetically coupled wave machine, reaching more than 30-feet high along the 85-foot-long building façade. The massive aluminum masts swinging just overhead may dance in graceful undulating patterns, or may break into unpredictable chaos with a gust of wind.
The building is clad with bioreactors filled with microalgae, which is a biomass later on used to generate energy. In total, 129 bioreactors measuring 2.5m x 0.7m have been installed on the south-west and south-east faces of the four-storey residential building to form a secondary façade. The panels are able to rotate around a vertical axis towards the sun. Heat produced in the panels can be used inside the building. It produces about 1/3rd of the demand of the dwellings. The more dense the panels are, the more solar glare is kept out of the building. In winter the panels let a lot of light trough, in summer the sunlight is partially blocked. This means that photosynthesis is driving a dynamic response to the amount of solar shading required, while the micro-algae growing in the glass louvres provide a clean source of renewable energy.
The Soft House demonstrates how domestic infrastructure can become ‘soft’—engaging flexible living concepts, carbon-neutral solid wood (brettstapel) construction, and wireless building controls with responsive and performative textiles which create the public identity of the architecture. Flexible facade that harvests energy. The “Twisters” follow the sun through the day like a sunflower. On top of the roof a windsensor is placed. Once it starts to storm the twisters are positioned in such a way that they will catch the least amount of wind. Each house has 24 accu’s where generated energy can be stored. The storage capacity is 21,12 kWh and is enough for an average household use of 2 days. The users are able to regulate the amount of daylighting entering the house as well as their view. The optimum position of the twisters is changed according to the sun, the time of the day, the season and the weather.
Lotus Dome
Various Locations

Architect: Studio (Daan) Roosegaarde
Year: 2011
Function: Artwork
Surface: 4 m²
Type of response: Passive
Climate type: material dependent

Lotus is a living wall composed of smart foils that fold open in response to human behavior. Inside the dome is a light that follows movement of humans walking around the dome. The bi-metal aluminium foils respond to heat from this lamp and start to curl, which causes the surface to let more light through. Walking by Lotus, hundreds of aluminum foils unfold themselves in an organic way; generating transparent voids between private and public. The sensors are an active system. The movement of the facade is passive though.
The membrane encases a former warehouse frame and is made of Ethylene Tetra Fluoro Ethylene (ETFE). The air chambers include solar-powered sensors that cause the chambers to contract and inflate in accordance to the amount of sunlight that hits them. In summer, the membrane acts as a sunscreen, filtering heat and UV rays by 85%. The filter is created by inflating the chambers with a fog-like Nitrogen mix, which block solar rays and creates cooling shade. In winter, the membrane opens to soak up solar rays, maximizing the transmission of light and heat to the interior. The Media ICT’s roof is covered with a garden and flecked with photovoltaic cells for solar collection. To save on non-potable water consumption, Cloud 9 has installed a rainwater collection system. A giant cistern stores the water, which is then distributed into the building’s non-potable plumbing system as well as into a district cooling system, which helps air condition the building with cool water.
The Hub has a large number of ESD features and will incorporate strategies of water, waste and recycling management that are the equal of any ESD focussed building on the planet. In particular the outer skin of the Hub incorporates automated sunshading that includes 16000 sandblasted photovoltaic cells, evaporative cooling and fresh air intakes that improve the internal air quality and reduce running costs. The cells have been designed so that they can be easily replaced as research into solar energy results in improved technology and part of the northern façade is actually dedicated to ongoing research into solar cells to be conducted jointly by industry and RMIT. The entire building façade, in other words, has the capacity to be upgraded as solar technology evolves and may one day generate enough electricity to run the whole building. The inner skin is built up with dubbel glazed units with a low-e (low emmission) film that emits low levels of radiant energy.
With a total covered area of 16,500m², they will be among the largest climate-controlled glasshouses in the world, employing low-energy and renewable systems. The envelopes of both biomes are critical to their success. Both are designed to allow as much light as possible to enter so that the plants within can flourish; the hybrid structure of a gridshell supported by giant steel arches was informed by extensive daylight analysis. However, with high levels of sunlight comes heat gain and so to lessen the cooling load a retractable shading system will be deployed between the arches for use on sunny days. Rolled triangular sails of 8m x 10m will be concealed within the main arch sections and these will unfurl as required to provide shade. The choice of glazing is also fundamental to the façade design: the double-glazed units that enclose the biomes will have a low-e coating on the inner face of the outer pane to allow approximately 65% of the incident daylight through to the interior but only 35% of the solar heat.
Sharifi-Ha House

Tehran
Iran

Architect: Nextoffice – Alireza Taghaboni
Year: 2013
Function: Dwelling / Residential
Surface: 1400 m²
Type of response: Active (but on demand)
Climate type: mild, semi-humid climate (Csa)

The facade is characterized by turning boxen that lead the building’s volume to become open or closed, introvert or extroverted. These changes may occur according to changing seasons or functional scenarios. In summertime the house offers an open, transparent and perforated volume with wide large terraces. In wintertime the volume closes down, offering minimum openings and a total absence of those wide terraces. The facade changes shape on demand. When the turning boxex are closed, daylight is gained through the void in the middle of the house. The applied manufacturing technique is the same as used in theatrical scenes or car exhibitions when they use turning floors. A foldable handrail makes it easier and safer to rotate the boxes and use them afterwards again.

plan

section

characteristic element
detail
As with many buildings in Berlin, Friedrichstrasse has both a facade on the street-facing side as well as on the inner courtyard, so it was important that the architects consider both sides when designing for energy efficiency. The garden side is outfitted with operable shade screens that extend down over each window to protect the interior from the morning glare. Roll-out textile shades can be extended when needed, or retracted for more light once the sun has moved past its zenith. On the street side, the building features three two-story high bay windows, with a specially designed double-glazed facade. A series of vertical fins are integrated to the outside of the windows that can be angled to protect against the heat. Sustainability in construction and technology are already pre-certified with the GOLD award of the DGNB German Sustainable Building Council.
The architectural effect is a smoothly moving facade that is seamlessly integrated into the overall continuous skin of the pavilion. The facade consists of 108 kinetic lamellas that are supported at the top and the bottom edge. Beside their function to control light conditions the moving lamellas create animated patterns on the facade. The choreography will span from subtle local movements to overall waves effecting the whole length of the building. During daytime the kinetic lamellas are used to control solar input. They will be operated by energy gained through solar panels on the roof. The lamellas occupy more than 34,000 square feet, each one with a free span of 10 to 50 feet. The spears move when actuators apply compressive stress to the top and bottom of each one. The pressure creates a complex elastic deformation in each segment, causing the facade to open. Because upper and lower motors often have opposite power requirements the system can feed energy back into the local system to operate more efficiently.
The pure volume is 'honest' and 'direct' in its detailing. The pivotal windows add a subtle refinement to the principle of the puristic, modernistic box and introduce the quality of elegant, undulating movement. These window frames were specially designed in collaboration with the company Eurodeur. The envelope is characterized by aluminium framed glass panels that open up to the outside through a simple mechanistic pivot that plays on the original pivoting function of the bridge itself. The pivots are electronically actuated, which ensures a consistent and aesthetically rhythmic pattern for the open condition. From the energy standpoint this simple facade allows for good cross-ventilation of the restaurant.
The wall is clad on the outside with coloured aluminium sheeting, and 90 cm in front of this is a layer of more than 56,000 glass louvres (panels of 120 by 30 cm) that can be inclined at various angles. The blue and red colours that shimmer through this skin become increasingly subdued towards the top, eventually turning to white and finally giving way to a fully glazed dome. The space between the facade layers forms a thermal buffer and allows a natural circulation of air and ventilation. By night the facade is lit up by 4500 LEDs. North side glass bri-solei pieces are different from the south side ones. The ones in the north side are translucid (but transparent when concrete wall features a window) and the south side ones are transparent. Some of the pieces of the bri-solei, in the south facade, have photovoltaic plates to generate electricity for the building.
Low-energy, water-positive building in the city's dense urban core. The east is enclosed by a service core, the west opens and closes behind operable recycled timber shutters. North and South include operable windows and balconies down one side. Daylighting is minimized to limit solar-heat gain. Conditioned outside air is delivered to an underfloor ventilation system. The windows open automatically to allow cold night air to cool exposed concrete surfaces, which helps reduce the cooling demand in the morning by 20 percent. The operable west facade consists of two layers, a glass curtain-wall system and the outer skin of recycled timber shutters. The panels are individually mounted and actuated by the position of the sun (open in morning and close in the late afternoon). Plant boxes on the north facade provide the intended summertime shade, but certainly make for a dynamic facade that changes with the seasons.
III - Case studies placed on the world map
IV - Case studies placed on the map of Europe
PROJECTS WITH A SIMILAR CLIMATE
Temperate climate (Cfb)

- Friedrichstrasse 40, office
  Germany
- Thyssen Krupp Cube, Q1
  Germany
- EWE-Arena
  Germany
- F-House
  Germany
- St. Ingbert Town Hall
  Germany
- BIQ House
  Germany
- Living Room
  Germany
- Soft House
  Germany
- Hotel Amstelkwartier
  Netherlands
- Café Open
  Netherlands
- RMIT Design Hub
  Australia
- Solarlux NL
  Netherlands
- Sliding House
  United Kingdom
- Council House 2
  Australia
- Kiefer Technik Showroom
  Germany
- SDU Campus
  Denmark
VI - 8 movement concepts from nature for bio-inspired design
Sunflower
Follows the path of the sun

**Driver:** Growth  
**Reason of movement:** Best guess is that they need more heat to grow more seeds.

Sunflowers also do that amazing sun-following trick that makes these plants seem to possess some mystical powers. In fact this process is called heliotropism. Heliotropism means moving toward the sun. The stems of all actively growing sunflower parts - flowers and leaves - grow to face the sun in order to maximize photosynthesis. During the day, the stems elongate on the side away from the sun, tilting leaves and immature flowers toward the sun throughout the day and ending up facing west at sunset. When there's no light (so...night time), the other side of the stem grows, pushing the leaves and flowers back to the east where they will be facing the sun at sunrise. Growing leaves and immature flowers are green and actively photosynthesizing, and heliotropism provides them with 10-15% more sunlight than just sitting still. As soon as they mature, they usually end up facing east and staying there.
Fish Gills
Open and close to regulate the respiration of the organism

**Driver:** Muscles
**Reason of movement:** Bij opening and closing the gills, the water is pumped through them which makes respiration possible.

When a fish breathes, it draws in a mouthful of water at regular intervals. Then it draws the sides of its throat together, forcing the water through the gill openings, so that it passes over the gills to the outside. Gills usually consist of thin filaments of tissue, branches, or slender tufted processes that have a highly folded surface to increase surface area. The high surface area is crucial to the gas exchange of aquatic organisms as water contains only a small fraction of the dissolved oxygen that air does. Rather than using lungs “Gaseous exchange takes place across the surface of highly vascularised gills over which a one-way current of water is kept flowing by a specialised pumping mechanism.
Eye-lids
Protecting the eyes in multiple ways

Driver: Muscle
Reason of movement: Protection and maintaining of the eye

The human eyelid features a row of eyelashes along the eyelid margin, which serve to heighten the protection of the eye from dust and foreign debris, as well as from perspiration. Its key function is to regularly spread the tears and other secretions on the eye surface to keep it moist, since the cornea must be continuously moist. They keep the eyes from drying out when asleep. Moreover, the blink reflex protects the eye from foreign bodies.
Skin

Sensors and reacting on changes in environment

**Driver:** Muscles

**Reason of movement:** To regulate temperature of the human body. Protection layer of the body. Explore the environment and react to it.

The skin is the largest organ of the human body. The skin protects the body from harmful environmental factors such as dampness, cold and sunlight, but also from germs and harmful substances. It plays an important role in regulating body temperature. It is through our skin that we pick up sensory information: this is how we feel heat, cold, pressure, itchiness or pain. Some of this information triggers a reflex. The body can store water or deposit fat and products of metabolism in the skin. This is also the place where essential vitamin D is produced with the help of sunlight.
Feathers are fantastic insulation. Downy feathers trap tiny pockets of air next to the bird, allowing the bird to warm those pockets of air and hold that warm air around itself, preventing cold air from touching its skin. The more air trapped, the warmer the bird. Birds fluff up (the technical term for fluffing up is “ptiloerection”) in the cold to trap as much air in their feathers as possible.
Crocus

reaction on temperature by folding and thereby protecting inner core.

Driver: Plant growth caused by temperature  
Reason of movement: changes in temperature that make the inner or outer part grow faster. Protects the inner part from the flower from becoming too cold.

Other than Sunflowers it is warm temperatures that trigger cell growth in the crocus flowers. When the sun is shining and the air is warm, the cells on the inner surface of the flower petals grow more quickly than those on the outside of the petals. This causes the flower to open. Alternately, when night arrives and temperatures cool, the cells on the inner surface slow their growth, but those on the outer surface continue to grow at the same speed. This causes the flower to close. Hanabi Lamp (Tokyo, 2006) that folds the same way.

principle (already in form of interpretation by design)
The scales of seed-bearing pine cones move in response to changes in relative humidity. The scales gape open when it is dry, releasing the cone's seeds. When it is damp, the scales close up. The cells in a mature cone are dead, so the mechanism is passive: the structure of the scale and the walls of the cells composing the scale respond to changing relative humidity. Pine cones usually appear open because this is considered a more favourable condition for the seed dispersal and germination. This usually happens when the weather is warm and when they touch water or in cold conditions, they tend to close to avoid destruction.
Lotus leaves
Self cleaning capability

**Driver:** Genetics and form of the plant  
**Reason of movement:** Cleaning of the surface of the leaf

It is not really the plant itself, but the water sliding along the surface of the leaf that is the significant movement. As the water slides along the surface to the deepest point of the leaf, it gathers all the particles that are landed on top of the leaf. This way the leaf is cleaned.
Sources of reference projects

# 1 Manitoba Hydro
http://en.wikipedia.org/wiki/Manitoba_Hydro_Place
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# 27 Sharifi-Ha House

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# 29 One Ocean Expo

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**# 32 Council House 2**