Facade 2018 -
adaptive!

Editors in Chief:

Andreas Luible
Susanne Gosztonyi

Editors:

Mauro Overend
Laura Aelenei
Aleksandra Krstic-Furundzic
Marco Perino
Francesco Goia
Frank Wellershoff
Shady Attia
Uta Pottgiesser
Ulrich Knaack
Christian Louter

Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN
Engineering and Architecture
FH Zentralschweiz

COST
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Designing Adaptive Facades with a new holistic Eco-Design Approach

Nitisha Vedula a), Laura Aelenei b), Uta Pottgiesser c)

a) Hochschule Ostwestfalen-Lippe, University of Applied Sciences, Germany, vedulantsh@gmail.com
b)LNEG-National Energy and Geology Laboratory, Portugal
c)University of Antwerp, Faculty of Design Sciences, Belgium

Implementing the Eco-designed approach in the field of adaptive façade systems, primarily aims for the future sustainable targets to develop eco-friendly and socio-responsive technologies. This will be only possible when the adaptive façade systems track design strategies endeavouring to imitate the philosophy of "the self-sufficient unit in the nature called eco-system." With the understanding of the future sustainable targets of adaptive systems and analysing its sustainably efficient elements with the help of already existing and scattered classification schemes from the data base developed within the work of the Cost Action TU 1403 Adaptive Façade Network (AFN), this approach attempts to develop a novel matrix for re-analysing these adaptive façade projects with an eco-design approach. The aim of this approach is to examine whether these adaptive façade projects from the data base are able to seamlessly integrate themselves in this approach and to what extent. The eco-design approach on the basis of the contiguous natural environment (i.e. location and climate type), conceives the adaptive façade projects as a unit-cell in the eco-system, which should naturally attempt to be a self-sufficient unit. Understanding this approach, the various principles of the adaptive façade systems in the projects from the database are analysed. This leads to characterizing the approach in a matrix of the biotic components of eco-system (producers, consumers and decomposers) and abiotic components of eco-system (air, soil, water, temperature, pressure, inorganic substances, etc.). These two components work collectively due to the naturally occurring energy transfer principles in amidst, known as conduction, indirect-solar, direct-solar and ventilation. The matrix also further characterizes the biotic components into active and passive systems, in order to avoid any error in analysing both, the direct and in-direct influences of the adaptive façade systems inside the project. The eco-design approach attempts to thoroughly analyse the extent of integration of this approach in the field of adaptive façade systems and to apprehend the further scope of research and development for the related industry.

Keywords: Ecological approach, eco-friendly, adaptive, active and passive design systems.

1 Introduction

Recent studies show that in developed countries people spend on an average 90% of their time indoors (EU 2003). This trend reflects the exceptional requirement of a healthy indoor environment, which in turn will help in ensuring larger prospect of society welfare. Statistics of the countries represented at International Energy Agency (IEA), reveal that the 'buildings' peak as the primary energy dissipater at around 40% of the total energy (IEA 2013). In this context, it is of fundamental importance to devise strategies for the building stock that can be instrumental in achieving the energy efficiency and climate change goals set by different countries (IEA 2012). Building envelopes are positioned at the interface between exterior and interior, thus they have a dominant impact on a building's energy balance and can therefore play a large role in making the transition towards sustainable, energy-neutral buildings (EU 2015, IEA 2013-2). Until recently, the main focus of the building envelope design and development was on structural, passive and robust performance aspects (Knaack 2007). However nowadays, it is increasingly recognized and desirable to have a more flexibly behaving façade system, with "responsive, adaptive and dynamic" as the key words in disposition (Heiselberg 2012, Schumacher et. al. 2010, Wigginton and Harris 2002). Aiming to enhance the overall building performance, this next generation of façade technology consists of multifunctional and highly adaptive systems; wherein the building envelope possess the audacity to change its functions, features and behavior overtime in response to the transient performance requirements and boundary conditions.

Within this context, the European initiative- COST Action TU1403 "Adaptive Facades Network (AFN 2014)" was commissioned in the framework of EU COST (European Cooperation in Science and Technology). The main aim of this action plan is to harmonize, share and disseminate technological research on adaptive facades at a European level. By harnessing this source of knowledge, countries will contribute to the generation of new ideas and concepts at a fundamental and product/ system development level.

One of the goals of this initiative is to collect information about different types of existing adaptive façades (materials, components and systems), aggregating them in a case study data base and developing a detailed analysis. This process stretches boundaries in innovative solutions, characterizing methods and approaches for the near future.

In accordance to the initiative, a novel and appealing characterizing perspective for the adaptive façades termed as eco-design approach, is being proposed by the authors. With the understanding of the sustainable targets in adaptive systems and analyzing the green elements in already existing scattered classification schemes (from the data base of Cost Action TU 1403-Adaptive Façade Network), this holistic approach is being proposed to design adaptive facades with a unified and systematic characteristic. This approach is applied on some of the case studies at the Adaptive Façade Network data base to analyze their existing effectiveness. The aim of this paper is to examine whether the existing adaptive façade projects are able to seamlessly integrate themselves in the Eco- design approach and if yes, to what extent.

2 Methodology of Eco-Design Approach

The basis of the Eco-designed approach relies in the use of ecological design principles and strategies to design the built environment and the ways of life, keeping up the benign and seamless integration with the natural environment including the biosphere (Yeang, 2006). As per eco-design approach: the eco-system is a self- sufficient and independent unit in nature which includes the living entities (plants, animals, decomposers) and the non-living environment (soil, air, water). This system requires only the input of solar energy for its functioning. The main components of eco-System are classified as follows:

A Abiotic Components, the non-living environment: Consists of the physical environment in the form of soil, water, air along with the inorganic substances like CO2, Nitrogen, O2, Water, Phosphorus, Sulphur, Sodium, Potassium, Calcium, etc. Climatic factors like light, temperature, pressure and humidity accompany it.

B Biotic Components, the living environment (Fig.1): This consists of a community of inter-dependent living organisms:

- - Producers: Synthesize their own food. E.g. Plants.
- - Consumers: Dependent on others for food. E.g. Human beings.
- - Decomposers: Consume the waste remains and produce required raw material for the producers.

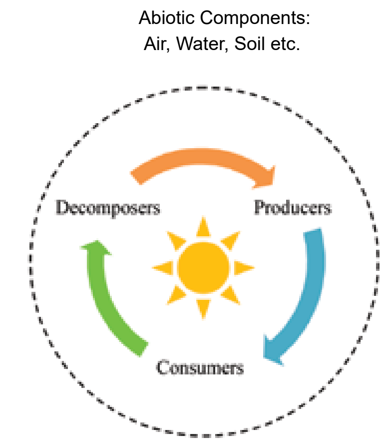
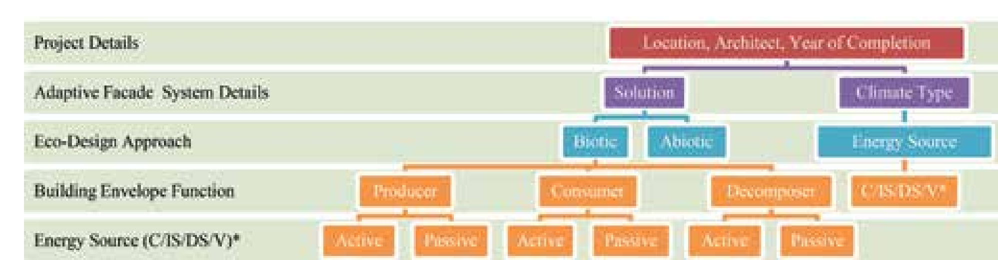


Fig. 1 One-way cycle of biotic components which function with the support of abiotic components and sun as source of energy

The eco-design approach for adaptive façade systems replicates the same principle and believes that the already acknowledged novel adaptive systems and principles implied in the projects should be analyzed as a unit-cell in the eco-system, which naturally attempts to be self-sufficient and follows the cycle of the eco-system as explained earlier in Fig 1. This leads to the characterization of the following matrix:

- Abiotic components of the adaptive façade: It consists of the supporting environment required for the system to function seamlessly, this includes air, soil, water, temperature, pressure, inorganic substances, etc., which evidently is governed by the climate and location of the project.
- Biotic components of the adaptive facade: It consists of the novel ideas and approaches involved in the adaptive façade system, which functions in tandem with the Abiotic components. However, eco-design approach suggests further characterizing of its biotic components in order to analyze its natural competency to be a self-sufficient component. These can be classified as follows:
  - Competency as producers: To synthesize the adaptive façade system, either actively (E.g. mechanized and computerized adaptive façade systems) or passively (E.g. vernacularly adapted façade systems).
  - Competency for consumers: To extract the benefits from the adaptive façade system for the users, either actively or passively. (E.g. in the form of thermal or visual comfort).
  - Competency as decomposers: In consuming the extracts from the façade system and producing raw ingredients to support the adaptive façade system as an independent unit cell, either actively or passively.

The abiotic and biotic components of the adaptive façade system work collectively due to the naturally occurring principles of energy transfer within, termed as conduction, indirect-solar, direct-solar and ventilation. This comprehensive description of the eco-design approach in adaptive façade system has been created as a matrix and is shown below in Fig. 2.



*Where; Heat Flow: C = Conduction; S= Indirect Solar; DS= Direct Solar; V= Ventilation

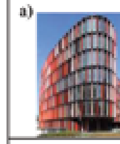
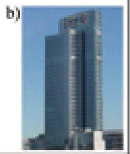
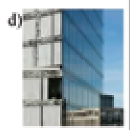
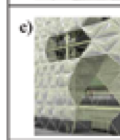
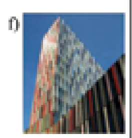
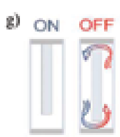
Fig.2. Matrix developed for eco-design approach to design adaptive facades with a unified and systematic characterization.

Consequently, the eco-design approach is applied to some of the existing case studies from the Cost Action data base. Taking into account the main goal of the overall performance of the adaptive façade system with respect to usability and acceptance by the users, the approach has been classified into following objectives:

- Analyzing –The case studies of the available adaptive façade elements.
- Evaluating and refining - With respect to the previously investigated information on new approaches and technologies.
- Re-Analyzing - As per Eco-design approach where development of adaptive façade systems can be improved with a holistic approach, leading to investigation and implementation of high-potential innovative components, materials, control systems in the course of the action.

The following projects from the already existing data base, were sought for the analysis under this new holistic approach:

A Oval Cologne Offices, Cologne, Germany (Albajar 2012)
B Altra Sede Regione Lombardia, Milan, Italy (Renato 2010)
C Campus Kolding, SDU University, Kolding, Denmark (Arch Daily 2015)
D Allianz Headquarters, Wallisellen, Switzerland (Frearson2014, WAA 2017)
E Media-TIC, Barcelona, Spain (Archi Travel online architecture guide 2013, Ruiz-Geli 2011)
F KfW Westarkade, Frankfurt, Germany (Wainwright 2012)
G WaMaFat - Switchable Insulation, Ludwigshafen, Germany (Thibault 2015)

Examples	Name / Location / Architect / Year/ Climate	Eco-Design Approach			
		Energy Source/ Abiotic Components	Biotic components		
			Producer	Consumer	Decomposer
a) 	Oval Cologne Offices / Cologne, Germany / Sauerbruch Hutton Architekten, Berlin / 2010/ Marine West Coast; Cfb	Direct Solar Radiation, Ventilation/ Temperature, Wind, Air Pressure	Double Skin Ventilated Façade[P] / Automated Seri-graph printed vertical Louvers.[A]	Visual / Thermal Comfort/Indoor Air Quality.[P] Individual Comfort Control.[A]	Improves energy performance.[P]
b) 	Altra Sede Regione Lombardia / Milan, Italy / Pei Cobb Freed & Partners, Caputo Partnership, SD Partners / 2009/ Marine West Coast; Cfa	Solar Radiation, Conduction/ Temperature	BIPV (Building Integrated Photo-Voltaic) into Structural Glazing System.[A)(P]	Visual/ Thermal Comfort.[A] [P]	Improves energy performance.[P] Produces clean energy.[A]
c) 	Campus Kolding, SDU University / Kolding, Denmark / Henning Larsen Architects / 2014/ Marine West Coast Cfb	Direct Solar Radiation, Ventilation/ Wind, Temperature	Dynamic, perforated & triangular vertical shading for solar insulation [A], also performing as a windbreak during cold climate.[P]	Visual/ Thermal comfort.[A] [P]	Improves energy performance.[P]
d) 	Allianz Headquarters / Wallisellen, Switzerland / Wiel Arets Architects (WAA) / 2014/ Marine West Coast; Cfb	Solar Radiation/ Temperature, Aluminum, Silver	Solar heated close cavity glazing system with highly conductive& reflective Aluminum-Coated Silver overhangs[P];controlled by computer algorithm.[A]	Thermal/ Visual comfort .[A] [P]	Improves energy performance.[P]
e) 	Media-TIC / Barcelona, Spain / Enric Ruiz Geli, Cloud 9 / 2007/ Mediterranean; Csa	Solar Radiation/ Temperature, Liquid Nitrogen.	Nitrogen Pneumatic Light sensor ETFE facades.[A]	Thermal/ Visual comfort.[A] 90% less solar gain[A], efficient solar transmittance.[A]	Improves energy performance.[P] 65% less Co2 emission. [A]
f) 	KfW Westarkade / Frankfurt, Germany / Sauerbruch Hutton Architekten, Berlin / 2010/ Marine West Coast; Cfb	Solar Radiation, Ventilation/ Temperature, Wind, Air Pressure	Automated [A] Saw-Toothed double skin ventilated Façade, creating an air pressure ring to regulate the prevailing wind movement through it. [A]	Indoor Air Quality; annually 8 month's natural ventilation. [A] Thermal Comfort.[P]	Improves energy performance. [P] Captures 5 differentwind directions to maintain an air flow never exceeding 6 m/s.[A]
g) 	WaMaFat - Switchable Insulation / Ludwigshafen, Germany / Nikolaus Nestle, BASF SE & WaMaFat consortium / 2014/ Marine West Coast; Cfb	Conduction/ Temperature, BASOTECT (a melamine foam, faintly conductive) insulation panel.	Façade element with switchable U-value, with multiple BASOTECT Insulation panels to maintain controlled convection inside a closed module. [A]	Optimized or non-optimized thermal comfort [A] [P]	When non-optimized; 10% reduction in the cooling demand. [P] When optimized 33.3% reduction in the cooling demand. [A]

Wherein,
Cfb = Warm temperate, fully humid, warm summer; Cfa = Warm temperate, fully humid, hot summer; Dfb = Snow, fully humid, warm summer; Csa = Warm temperate, fully humid, hot summer; (A) = Actively performing biotic components in Eco-design approach; (P) = Passively involved biotic components in Eco-design approach.

Table 1: Eco-design matrix: Comparison of the selected projects under the eco-design approach, as presented in fig. 2

3 Results and further Developments

As per the Köppen Climate Classification System (Hans, C. 2007), the double skin adaptive facades presented in projects a), c), d), f) fall under the same climatic type i.e. Cfb (Warm temperate, fully humid, warm summer), supported with similar energy source (Direct & Indirect Solar Radiation and Ventilation), evidently leading to similar abiotic components (i.e. the supporting environment; Temperature, Wind, pressure).

Despite that, these 4 projects do not utilize the abiotic components correspondingly and efficiently, as defined below in the Table 2. The resulting biotic components of the adaptive façades (i.e. the novel ideas and approaches of these adaptive façade system) although share a resemblance, but when deeply analyzed, the projects c) and d) do not absorb the supporting natural environment effectively.

		Abiotic Components applied		
	Abiotic components attainable in Climate type; Cfb	Temperature	Wind	Air pressure
a)	Oval Cologne Offices, Cologne, Germany	✓	✓	✓
c)	Campus Kolding, SDU University, Kolding, Denmark	✓	✓	x
d)	Allianz Headquarters, Wallisellen, Switzerland	✓	x	x
f)	KfW Westarkade, Frankfurt, Germany	✓	✓	✓

Table 2: Comparison of the abiotic components applied in the projects falling under the same Climate Type Cfb (Warm temperate, fully humid, warm summer) in the Eco-design matrix in Table 1.

Under the section biotic components in the eco-designed matrix, as shown in Table.1, the dissimilar competency of the adaptive facades, evolved as a producer, is also effortlessly observable. Likewise, its consequential impacts and efficiency of the adaptive façade system (as a self-sufficient unit cell) with its active and passive results and involvement are furthermore divergent.

Under the section biotic components in the eco-designed matrix, as shown in Table.1, the competency of the adaptive facades as a decomposer, shows the inefficiency of most of the projects, in actively consuming the extracts from the façade system and producing back the raw constituents to support it as an independent unit cell.

The adaptive façade projects b), e), g) in relation to the previously discussed projects, belong to other different climate types. They share some similar abiotic components, resulting to comparable competency as a producer, on the other hand resulting to completely different and novel concepts.

In this way, the eco-design approach can compile the vast and scattered information about the adaptive façade systems under the same matrix. And it can aid to extract and analyze multiple information at the same time.

4 Conclusion

In the framework of the European Initiative COST Action TU1403 “Adaptive Façade Network (AFN2014)” a number of examples of adaptive façade elements (materials, components and systems) were collected in a data base for developing a detailed analysis to support an increase in innovative solutions, characterizing methods and approaches for the near future.

Some of these case studies were selected in order to test a new holistic approach for charactering the adaptive façades, termed as, Eco-design approach. This approach generates the possibility of channelizing the already existing, vast and scattered information on the adaptive facades. It follows a qualitative methodology which can also lead to a quantitative analysis (in terms of energy performance) for future developments and research.

With this approach it will be possible to lead the future adaptive façade technologies to derive from ecological design principles and strategies, which could be integrated benignly and seamlessly with the natural environment that includes biosphere.

5 Acknowledgements

This research paper is the outcome of the Short Term Scientific Mission (STSM) held under COST Action TU 1403 in the year 2017. The authors would like to cordially thank the European Union and COST for all the opportunities and support.

6 References

Adaptive Façade Network (AFN): EU COST-ACTION TU 1403 (2014). http://tu1403.eu/. Accessed 13 July 2017.

Albajar, B.: Colourful glass louvers on office in Colonia, S&H [212]. FILT3RS Design of windows Web. http://filt3rs.net/case/co-lourful-glass-louvers-office-colonia-sh-212 (2012). Accessed 17 July 2017.

Arch Daily: SDU Campus Kolding / Henning Larsen Architects. https://www.archdaily.com/590576/sdu-campus- kolding-hen-ning-larsen-architects(2015). Accessed 18 July, 2017.

Archi Travel online architecture guide: Media-TIC. http://www.architravel.com/architravel/building/media- tic/(2013). Accessed 20 July 2017

Architect Science:Towards a new architecture+ Energy. Science for Sustainable Architecture. http://www.architectscience.com/images/Towards_A_New_Architecture_Energy_-_Part_2.pdf (2012).Accessed 17 July, 2017.

Arch Record + Sauerbruch Hutton: Prismatic Sustainable Buildings Imitate the changing Seasons. ALPOLIC Metal Composite Materials Web. http://www.alpolic-americas.com/prismatic-sustainable-buildings-imitate-the- changing-seasons/(2012). Accessed 17 July 2017.

European Commission (EU): IP/03/1278. Indoor air pollution: new EU research reveals higher risks than previously thought. http://europa.eu/rapid/press-release_IP-03-1278_en.htm (2003). Accessed 01 August 2018

European Commission (EU): Energy-efficient buildings. Multi-annual roadmap for the contractual PPP under Horizon 2020. http://ectp.ectp.org/cws/params/ectp/download_files/36D2981v1_Eeb_cPPP_Roadmap_under.pdf (2015). Accessed 01 August 2018

Frearson, A.:Allianz Headquarters by Wiel Arets features glass fritted to reference Mies’ Barcelona Pavilion (2014).https://www.dezeen.com/2014/03/26/allianz-headquarters-wiel-arets-architects/Accessed 19 July 2017.

Hans, C.: Koeppen climate classification: as a diagnostic tool to quantify climate variation and change. http://hanschen.org/koppen/#classification (2007).Accessed 08 August 2018

Heiselberg, P.: IEA ECBCS Annex 44. Integrating Responsive Elements in Buildings. Project Summary Report. http://www.ecbcs.org/Data/publications/EBC_Annex_44_PSR.pdf (2012). Accessed 01 August 2018

International Energy Agency (IEA): Transition to Sustainable Buildings. Strategies and Opportunities to 2050. Executive Sum-mary. https://www.iea.org/Textbase/npsum/building2013SUM.pdf(2013). Accessed 01 August 2018

International Energy Agency (IEA). World Energy Outlook 2012.https://webstore.iea.org/world-energy-outlook- 2012-2 (2012). Accessed 01 August 2018

International Energy Agency (IEA): TechnologyRoadmap. Energy efficient building envelopes. https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvel opes.pdf (2013-2). Accessed 01 August 2018

Knaack, U.: Facades - Principles of Construction, Birkhäuser, Basel (2007).

Renato, M.: Vetri Fotovoltaici per Integrazione Architettonica (Building Integrated Photovoltaics). Energy glass Solar and Glass Architecture

https://www.fresialluminio.it/images/Fresia2009/ConvegnoPoli270309/relazione-macconi-27-03-09.pdf (2010).Accessed 17 July 2017.

Reardon,C.:PassiveCooling. Your Home. Australia’s guide environmentally sustainable homes. http://www.yourhome.gov.au/sites/prod.yourhome.gov.au/files/pdf/YOURHOME-PassiveDesign- PassiveCooling.pdf (2013). Accessed 18 July, 2017

Ruiz-Geli, E.:Media-ICT building CZFB, 22@. Barcelona. Ruiz-geli projects. http://www.ruiz-geli.com/projects/built/me-dia-tic(2011). Accessed 20 July, 2017.

Schumacher, M., Schaeffer, O., Vogt, M.: Move: Architecture in Motion - Dynamic Components and Elements, Birkhäuser, Basel (2010).

Thibault, P.: Closed translucent fac¸ ade elements with switchable U-value - A novel option for energy management via the façade. Energy and Buildings 86 (2015) 66–73.www.elsevier.com/locate/enbuild(2015). Accessed 24 July 2017.

WAA:Allianz Headquarters.http://www.wielaretsarchitects.com/en/projects/allianz_headquarters/ (2017). Accessed 19 July 2017.

Wainwright, O. (2012). KfW-Westarkade banking HQ, Frankfurt, by Sauerbruch Hutton. Bdonline.co.uk. https://www.bdonline.co.uk/technical/ Accessed 24 July 2017.

Wigginton, M., Harris, J.: Intelligent Skins, Butterworth-Heinemann, Oxford (2002). Yeang, K.:Eco Design: A Manual for Ecological Design: Wiley Academy, London (2006).