Climate Adapted Façades in Zero-Waste and Cradle to Cradle Buildings – Comparison, Evaluation and Future Recommendations, e.g. in Regard to U-Values, G-Values, Photovoltaic Integration, Thermal Performance and Solar Orientation

Alexander Kader
German University of Technology in Oman (affiliated with RWTH Aachen), P.O.B. 1816, PC 130 Muscat, Oman

alexkader@gmx.de, alexander.kader@gutech.edu.om

Abstract. The construction methods we are using today on a broad scale are highly unsustainable in regard to their resource efficiency. Fundamental improvements are necessary in order to change towards a more ecological future. The integration of reusable building components could be an adequate option to significantly reduce the ecological deficits we are facing today. The concepts of Zero-Waste and Cradle to Cradle are seen as viable solutions for the future. The few already existing Zero-Waste and Cradle to Cradle buildings are currently representing the most advanced construction standards of resource efficient design. In regard to their façades, however, there is still a high improvement potential. Therefore, methods have been elaborated within this research which demonstrates how the façades of Zero-Waste buildings can be strongly optimised. In particular, this research poses the question: with which interventions can we improve the performance of façades of Zero-Waste buildings? Which interventions are most important and how can we prioritize them? For example, which role does the insulation capacity of the building skin play in comparison to the building’s capability for natural ventilation and external shading? Within this paper, at first, the façades of selected existing Zero-Waste and Cradle to Cradle inspired buildings are examined and critically evaluated in regard to their u-values, g-values, photovoltaic integration, thermal performance and solar orientation. Furthermore, criteria such as sun exposure of glazed areas, natural ventilation capacity through façade openings etc. are investigated. Thereafter follows an assessment in the form of a list about which interventions could significantly improve the façade’s performance in regard to energy efficiency. The approaches include active strategies, such as improving the u-values, photovoltaic energy generation and passive strategies, such as enabling natural ventilation through the façade and external shading of sun exposed glazed areas. The selected case study buildings in Germany are “Aktivhaus B10” in Stuttgart by Werner Sobek, “Woodcube Building” in Hamburg by IfuH Architects and Architekturagentur, “ICON Rheinlanddamm” in Dortmund by William McDonough and Partners. In order to recommend which interventions are the best applicable in the relation between ecological performance and cost, the paper concludes with a prioritisation of the suggested improvement options. Overall, it demonstrates that the building’s overall energy performance can be significantly improved by adapting the façades towards a better implementation of passive strategies which take strong advantage of the project site’s individual climatic conditions.
1. Introduction
In contrast to a number of other sectors such as the car industry with a recycling rate of at least around 90% - the construction and demolition sector remains underdeveloped in regard to the advancement towards effective concepts to reuse building parts. Many building parts today are neither reusable nor recyclable, generating an enormous amount of waste within the construction industry. It is important to analyse and understand now, more than ever, why our current construction methods waste so much material and why our current buildings are so energy hungry. It is also worthwhile reflecting on the roots of this ever-increasing energy dependency, evolving from contemporary architectural components such as curtain glass facades, the lack of flexibility and adaptability of most buildings and their considerably short life spans [1]. Amid the growing trends of globalization, it becomes increasingly necessary to study the existing authentic built heritage that exhibits qualities such as recognizing local identity and unique characters of the location, thus subsequently identifying passive building strategies that have been successfully applied hundreds of years ago [2]. Keeping these passive strategies in mind, in light of industrialization of every single sector in the world today, it is also time to consider the same for the construction industry. Industrialization of construction would imply the prefabrication of certain elements off site, thus minimizing pollution, waste land-fill, manpower required on site and ultimately construction time. Prefabricated construction also ensures a certain level of building flexibility, thus ensuring that at any point of the building’s lifetime, parts of the building can be repaired, replaced or reused for other purposes without the need for their demolition [3].

The implementation of reusable building components could be an adequate option to significantly reduce the ecological deficits we are facing today. The concepts of Zero-Waste and Cradle to Cradle are to be seen as reasonable solutions for the future [4]. The few existing Zero-Waste and Cradle to Cradle related buildings currently represent the most advanced construction standards of resource efficient design. With respect to their facades, however, there still exists a high optimisation potential. For this reason, methods have been elaborated within this research demonstrating how the façades of Zero-Waste and Cradle to Cradle buildings can be strongly improved.

Considering that the façade is the main parameter that influences the energy performance of buildings, façade elements need to be designed to provide the buildings with the necessary flexibility needed in terms of energy flow and thermal comfort. Building envelopes need to behave as energy efficient mechanical systems, able to respond to non-continuous, changing external surroundings. Theoretically, this steps back from the common misinterpretation where the idea “The house is a machine for living in” is translated to: contextual qualities of a building must be disregarded and a one fit for all solution must be implemented. Instead, building envelopes must now be treated such that they once again integrate more frequently in its construction elements that are “alive”. In practice, this means that to reach the prescribed levels of efficiency and functionality, the façade needs to be changed or adapted. Subsequently, this idea of buildings being machines to live in would mean that buildings could active and passively respond to the life of its inhabitants. In the context of zero energy buildings, adaptive façades would be able to provide controllable insulation and thermal mass, radiant heat exchange, ventilation, energy harvesting, daylighting, solar shading or humidity control [5]. Therefore, the adoption of adaptive façades provides opportunities for significant reductions in building energy use and greenhouse gas emissions, while preserving the thermal and visual comfort of occupants. By combining the complementary beneficial aspects of both active and passive building principles into the building envelope, climate adaptive facades can draw upon the concepts of adaptability, multi-ability and evolvability [6].

2. The façades of current zero-waste and cradle to cradle buildings
When analysing facades of existing zero waste and cradle to cradle buildings, it becomes inherently important to understand the role of the façades, for example in regard to insulation capacity of the
building and its potential for natural ventilation and external shading. Within this chapter, at first, the façades of selected existing Zero-Waste and Cradle to Cradle buildings are examined in regard to their u-values, g-values, photovoltaic integration, thermal performance, orientation and embodied energy. Thereafter, the buildings’ efficiency is further analysed through the investigation of criteria such as sun exposure of glazed areas, natural ventilation capacity through façade openings, solar gains, sun shading.

The selected case study buildings are “Aktivhaus B10” (Figure 1) in Stuttgart by Werner Sobek, “Woodcube Building” in Hamburg by IfuH Architects and Architekturagentur, “ICON Rheinlanddamm” in Dortmund by William McDonough and Partners. The Woodcube and ICON buildings incorporate Zero-Waste and Cradle to Cradle principles to a great extent, but not entirely, considering there still being some elements of reinforced concrete.

![Figure 1. Sketch of Aktivhaus B10 Module (Source: author)](Image)

![Figure 2. Woodcube, Hamburg, South East Elevation (Source: author)](Image)

![Figure 3. ICON Rheinlanddamm, South East Elevation (Source: author)](Image)

The “Aktivhaus B10” is part of a research project examining how innovative materials, structural designs and technologies can improve our built-up world in a sustainable manner. Designed by Werner Sobek Group in the year 2014 and located in the Weissenhof Estate in Stuttgart, the B10 module is a prototype of the Aktivhaus concept developed by Werner Sobek as well. The project is a single-storey residential unit of dimensions 14.5m x 6m and a height of approximately 3m. Standing on a steel frame with eight steel supports, the building has a gross floor area of approximately 87m². The main construction material of the B10 module is wood. Besides being a building that does not create any emissions, it has also achieved an energy plus standard generating an energy surplus of approximately two times more than it consumes. The building is able to adapt continuously to the changing conditions and requirements of the interior and exterior spaces; in addition to this, the building utilizes active methods such as building automation and energy control, and passive methods such as closing the building on three sides and making full use of an extremely well insulated glass façade. After the project’s test phase of two years in Stuttgart, the apartment and office unit has been put up at another location in 2019. This is also part of the sustainable concept: to be able to subsequently change, move and completely reuse the building or building parts without any difficulties [7]. After the building’s life cycle, all building parts can be completely transferred either into “biological nutrients or they can be technical nutrients that will continually circulate as pure and valuable materials within closed-loop industrial cycles” [8]. Its components are fully recyclable, and take only a day to assemble; and the fact the modules can be stacked suggests they could be suited to high-density cities.

The “Woodcube” building in Hamburg (Figure 2), Germany, has been designed by IfuH Architects from Berlin and built by Architekturagentur from Stuttgart. It was completed in 2013 as part of the International Building Exhibition in Hamburg-Wilhelmsburg. The five storey building has the form of
a cube with the dimension of 15.1m x 15.1m x 15.6m (length x width x height). It contains eight apartments and has a total gross floor area of 1479 m². Most building parts are prefabricated and consist of untreated wood. Basement and staircase core, however, are made of reinforced concrete. The Woodcube nearly reaches the passive-house certification energy standard while also achieving a CO₂-neutral life cycle assessment. The thicknesses of the walls are a total of 32 cm of massive wood and a layer of wood soft fibreboard. Exterior walls are load bearing and serve as an insulation and a fire-protection layer. Additional insulation is established by the 4cm thick layer of wood soft fibreboard. Special patterns engraved onto the surface create enclosed air cavities further contribute to achieving an effective insulation. Meanwhile, horizontal wooden barriers in the substructure of wood cladding confine the vertical spreading of fire. The constructive system is consisting of load bearing walls and ceiling slabs. The prefabricated wooden construction is part of modular building kit developed, produced and marketed by the company Thoma Holz from Austria [9].

The “ICON Rheinlanddamm” building in Dortmund (Figure 3), Germany, has been designed by William McDonough + Partners from Charlottesville, USA and will be realized in cooperation with IAA architects from Enschede, Netherlands. It is scheduled to be completed in 2022. The office building has six storeys and its dimensions are approximately 80m x 50m (length x width). The upper floors have terraces. The building features a number of special characteristics including its green façade elements on its front side and green interior walls in the atrium. The building has a gross floor area of 22,300 m² and the rental space is approximately 13,000 m². The construction system consists of a reinforced concrete skeleton. The façade consists of a curtain wall with aluminium panel elements. The mass of concrete slabs is used for cooling and heating of the building, making use of a combination of passive heating and cooling strategies to cut down on the building’s overall energy consumption significantly. The building is designed as a material bank for future generations. Identifying the long-term value characteristic to all materials, both biological and technical materials used in this building have been ensured to be demountable and reusable in the future. For instance, the exterior facade is a unitized and prefabricated high-performance curtainwall system, which not only reduces volume, waste, and construction time, but can also be disassembled easily for future reuse [10]. Besides this, many building parts are made of cradle to cradle certified materials or components in order to be reused when the building’s life cycle comes to an end [8].

2.1. Façade properties of the three case study buildings
When examining case studies for Zero-Waste buildings, it is important to analyse critically the building façades and thus identify active and passive strategies that have already been realised in these buildings, making them successful Zero-Waste structures. Consequently, the next steps must be to recognize the potential and methods of improvement of these façades, reflecting this knowledge onto the construction of all future buildings.

The two tables below comprise of a façade elements’ comparison between the three case study buildings. Opaque and glazed façade elements have been compared separately, closely studying their manner of treatment, thicknesses, materials, u-values, g-values and several other factors that determine their function as a building envelope. While the tables highlight the similarities and differences between the façade properties of the three case study buildings, it also draws attention to methods of façade treatment that are currently lacking and would further improve their role as Zero-Waste buildings. However, further comparative studies could be continued to advance this research.
Table 1. Comparison of opaque façade elements of the three case study buildings

| OPAQUE FAÇADE ELEMENTS | Type                  | Materials                                                                 | Thickness approx. | U-Value | Green | Energy Generation | Thermal Storage Capacity | Integrated Ventilation    |
|------------------------|-----------------------|---------------------------------------------------------------------------|-------------------|---------|-------|-------------------|--------------------------|---------------------------|
| Aktivhaus B10          | load bearing prefab units | wood modules, reusable, textile skin, vacuum insulation panels | 27.0 cm          | 0.11 W/m²K | no    | no (only on the roof) | yes (interior side of façade) | only through glass façade |
| Woodcube Hamburg       | load bearing prefab panels | wood modules, reusable | 32.4 cm          | 0.19 W/m²K | no    | no (only on roof)  | yes (massive wood)     | yes, natural ventilation  |
| ICON Rheinlandd.       | curtain wall, partly greened | aluminium panels, reusable | 30 cm            | 0.2 W/m²K approx. | yes (as bio-filters) | no (only on roof) | no | only through glass façade |

As demonstrated in the above table 1, a careful selection of eco-friendly materials has been made to ensure energy efficiency. While the u-values of all three building’s opaque façade elements are already on a high standard, especially for the Woodcube and Rheinlanddemm buildings this could still be improved. Despite the buildings’ energy generation through solar panels on their roofs, none of three case studies makes use of their façades for energy generation – a passive approach which could impact the buildings’ overall performance significantly. The table above also highlights the thermal storage and ventilation capacity of the façades, hence emphasizing on the importance of these façades being multifunctional and adaptable.

Table 2. Comparison of glazed façade elements of the three case study buildings

| GLAZED FAÇADE ELEMENTS | Glass Type | Frame Type | U-Values approx. | G-Value approx. | External Shading System | Automatization | Glass/Wall Relation |
|------------------------|------------|------------|------------------|-----------------|------------------------|----------------|---------------------|
| Aktivhaus B10          | 17 mm thick vacuum glazing | skyframe aluminium sliding windows | total: 0.83 W / m² K  | changeable from 0.038 to 0.38 | yes | automatic and manual | 27 : 73 |
| Woodcube Hamburg       | triple glazing | wood, openable and not openable elements | total: 0.8 W / m² K | 0.5 | yes (only on sun exposed windows) | automatic and manual | 24 : 76 |
| ICON Rheinlandd.       | triple glazing | aluminium, openable | total: 0.8 W / m² K | 0.5 | yes | automatic and manual | 42 : 58 |

Table 2 focuses on the comparison of glazed façade elements of the three case study buildings. The above data shows that external shading systems have been established, highlighting their importance in contributing to the building’s energy efficiency. The table also demonstrates the importance of
achieving a balanced glass to wall ratio. Besides this, other factors like frame type, u-value, g-value and automatization of external shading are compared and studied.

2.2. Deficit assessment of the analysed buildings
While the above analysed case studies represent some of the most advanced resource efficient existing building structures, there still remains an immense room for development. While the B10 module is exemplary in terms of its energy generation and facade adaptability, it utilizes expensive high-tech elements that require generous amounts of maintenance along with additional electrical energy. Also, their production has consumed a large amount of energy, the so called ‘embodied energy’. Besides this, the vacuum insulated panels used in the building’s façade are also expensive and also with a high amount of embodied energy. While this works for an exemplary prototype module, such sophisticated parts with high standards could prove to be challenging to maintain in mass produced prefab buildings.

With the single-storey residential house being closed on three sides, the Aktivhaus B10 does not make optimal usage of passive strategies such as cross ventilation and daylight exploitation to improve the atmospheric quality indoors. This partially stands true for the Woodcube as well, where while cross ventilation is ensured using ventilation shafts, daylight is not made optimal use of due to its low glass to wall façade ratio. Considering the building’s position at a location which often receives a low amount of sunlight, this results in frequent usage of electrical lighting inside the building. It is also evident that with the implication of thicker facades in both Woodcube as well as the ICON Rheinlanddamm building, the u-values and thus insulation qualities of the façade could be significantly improved.

While the ICON Rheinlanddamm building consists of some green façade elements when compared with Aktivhaus B10 and Woodcube, these appear to have primarily an iconic character instead of focusing more on their ecological functions and benefits. Meanwhile, none of the three buildings make use of their facades for energy generation – a strategy that would otherwise significantly contribute to their status as innovative energy efficient and ecological structures.

3. Result: Interventions to improve the energetic and ecological performance of the façades of future zero-waste and cradle to cradle buildings
After analysing and comparing the façades of the three case study buildings, this chapter contains a consideration of possible interventions with which we can improve the ecological performance of the façades of future Zero-Waste and Cradle to Cradle buildings. An assessment in the form of a list demonstrates which individual interventions could be applied. The proposed approaches include ‘active strategies’ such as improving the u-values and implementing energy generation, as well as ‘passive strategies’, such as enabling natural cross ventilation through the façade and providing automated external shading of sun exposed glazed areas (table 3). The façades could become energy generators in two ways: photovoltaic (built example: ‘Effizienzhaus Plus’ at Fasanenstraße in Berlin by Werner Sobek and his institute ILEK at the Technical University of Stuttgart) and solar warm water generation (built example: ‘Drehsolarhaus’ in Freiburg, Germany by Rolf Disch).

The building and construction sector needs a more ecological approach and the optimisation of façades can significantly contribute. To make façades more efficient, multiple functions which are flexible can be integrated. In addition to an enhancement of the energetic and ecological performance for the buildings, especially due to climate change adaptation, façades also have the potential to significantly contribute to improving the exterior comfort of urban environments. The German façade expert Wolfgang Priedemann states: “Thinking towards the future, very soon the building skin will serve to urban life. Building envelopes should help to reduce inner city overheating as well as emissions by pollutants and noise. Energy absorbing and energy generating façades, in contrast to energy reflecting façades, are providing further potentials towards a sustainable urban atmosphere.
The capacity of nocturnal cooling down of cities depends on the absorption quality of façades, among other factors” [11].

**Table 3.** List of individual enhancement options for future façades of Zero-Waste and Cradle to Cradle buildings

| Passive Design Methods                  | Enhancement Options                                                                                                                                                                                                 |
|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Natural cross ventilation can be enabled and regulated through façades which can adapt according to specific requirements |                                                                                                                                                                                                                       |
| All sun exposed glazed areas can be equipped with automated external shading. Thus, unwanted solar heat gains are minimized by preventing any sun incidence in glazed areas |                                                                                                                                                                                                                       |
| Solar gains can be directed into the building according to need, façades can adapt accordingly to regulate energy flows |                                                                                                                                                                                                                       |
| Green façade elements or shields can cool the building and its surroundings as an aftereffect of evaporation. This can have positive impacts on: a) the microclimate around the building; b) air quality by emission reduction, air purification, dust filtering; c) keeping the building cool in summer since a cooler outer façade reduces the overall heat transmission through the façade into the building |                                                                                                                                                                                                                       |
| To reduce strongly mirroring surfaces to avoid sun reflections to the surroundings, so that they cannot locally overheat the exterior space |                                                                                                                                                                                                                       |
| To reduce massive exterior façade surfaces which absorb sun rays and thus can overheat the exterior spaces |                                                                                                                                                                                                                       |
| Opaque façades with changeable u-value can enable a building to better adjust to different climatic conditions (for example with openable ventilation valves) |                                                                                                                                                                                                                       |
| Sound absorption: exterior surfaces of facades can be selected or made in a way that they become sound absorbers instead of sound reflectors; acoustic back reflections of (traffic) noise can be reduced by the façade surface |                                                                                                                                                                                                                       |
| Façade properties can be adjusted to their individual solar orientation. Properties of façade elements can be modified according to their orientation to maximise solar heat gains when needed. For example, façades oriented towards the south which are exposed to winter sun can have less insulation (or lower u-values and higher g-values) to enable solar warming, while façades without winter sun exposure can be equipped with more insulation than winter sun exposed parts |                                                                                                                                                                                                                       |
| Glazed façade areas can be designed in a way such that natural daylight use will be optimized |                                                                                                                                                                                                                       |
| Active Design Methods                  |                                                                                                                                                                                                                       |
| U-values can be improved, especially at façade parts which are not sun exposed during the heating period |                                                                                                                                                                                                                       |
| G-values can be improved at glazed areas which are sun exposed during the heating period |                                                                                                                                                                                                                       |
| Energy generation with façade integrated photovoltaics and warm water |                                                                                                                                                                                                                       |
| Thermal storage mass, to be installed at the façades’ interior sides |                                                                                                                                                                                                                       |
| The façades’ interior surfaces can integrate latent heat storage by using phase change material (PCM) |                                                                                                                                                                                                                       |
| Urban agriculture can be integrated as a green element on façades and balconies |                                                                                                                                                                                                                       |
| Electrochromic glass can be used to regulate the degree of privacy and illumination |                                                                                                                                                                                                                       |

4. **Prioritisation – comparison of performance versus cost**
Nonetheless, the question arises which interventions are most efficient and how can we prioritise them? In order to recommend which interventions are best applicable in the relation between ecological performance and cost, the following table 4 provides a prioritisation of the suggested improvement options.
Table 4. Estimation of the relationship between investment costs and ecological benefits

| COST   | high gains                                                                 | medium gains                                                                 | low gains                                                                 |
|--------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| low    | • directed solar gains  
• façade properties adjusted towards orientation | • maximisation of daylight use  
• reduction of acoustic back reflections, sound absorption of exterior surfaces |                                                                          |
| medium | • enable natural cross ventilation through the facades  
• automated external shading  
• building automatisation  
• opaque façades with changeable u-value  
• improved u-values  
• thermal massing | • façade integrated latent heat storage with PCM  
• improved g-values  
• reduce mirroring surfaces  
• reduce massive exterior façade surfaces |                                                                          |
| high   | • green shields  
• urban agriculture  
• energy generation | • façade integrated energy generation with photovoltaics  
• façade integrated solar warm water collectors  
• use of latent heat storage | • electrochromic glass |

The approach of this paper is conceptual. All suggested improvement options are preliminary assessments and relative. Each of the points needs a much deeper elaboration and needs to be proven in further studies.

5. Conclusions

To summarise the above, this study demonstrates that a building’s energetic and ecological performance can be significantly improved by optimising the façades according to the criteria as explained below.

Passive strategies like the ones elaborated above could be implemented to a more extensive degree considering that a project site’s individual climatic conditions in most cases offer a much higher potential for use. In addition, the thermal comfort of a building’s interior space can be enhanced not only through the use of effective façade insulation, but also by other means, for example by utilizing the opaque façade’s inner surfaces as active tools that participate in the optimization of energy use. For instance, façades could be modified to regulate interior temperatures with a layer of latent heat storage, or by applying the simple technique of thermal massing.

Similarly, the exterior comfort of a building’s surroundings could also be enhanced by façades. The overheating of surroundings resulting from the sun’s reflection on the outer façade surface could be minimized, for example by the use of green façade shields, thus strongly improving the entire microclimate of a building’s site. Meanwhile, the green façade elements could constitute a powerful incubator for sustainability in multiple ways for the building itself, despite the additional costs for construction and maintenance.

In order to cater to the wide range of environmental and user specific requirements, façades have to fully unfold their potential; they have to better adapt to local conditions and different needs for usability and they have to constitute multiple functions at the same time. Once their multiple functionalities are established, multiple advantages will be achieved.

Overall, it can be stated that setting out for a better ecological future, the standards for façades will become a lot more advanced, implementing approaches that employ them as active participants in a
building and its inhabitants’ life cycle. Starting off with minimal enhancements that are cost effective and easy to establish, the construction industry could very well advance towards achieving this goal of an ecological, resourceful future.

References
[1] W. Kloepffer, “Life cycle sustainability assessment of products”, Life Cycle Assessment 13: pp. 89-94, 2008.
[2] S. Lehmann, and R. Crocker, “Zero waste in sustainable architecture and design at the household and building scale”, Designing for Zero Waste: Consumption, Technologies and the Built Environment, Earthscan, Routledge Publishers, New York, pp. 209-210, 284-287, 2012.
[3] B. Berge, “Reduction of energy consumption in the building industry” The Ecology of Building Materials, Architectural Press of Elsevier Linacre House, Oxford, UK, pp. 21-28, 2009.
[4] M. Hegger, C. Fafflok, J. Hegger, and I. Passig, “Aktivhäuser entwickeln: Passive Maßnahmen”, Aktivhaus – Das Grundlagenwerk, Callway, pp. 130-131, 2013.
[5] D. Aeleneia, L. Aeleneic, and C. P. Vieirab, “Adaptive Façades: concept, applications, research questions”, Proceedings of the 4th International Conference on Solar Heating and Cooling for Buildings and Industry, Science Direct, pp. 269-271, 2015.
[6] M. W. Lennartz, and S. J. Freitag, “Multi-storey buildings”, New Architecture in Wood: Forms and Structures, Birkhäuser Basel, pp. 125 – 128, 2015.
[7] DBZ Deutsche Bauzeitschrift, “Neues Bauen im Smart Grid Aktivhaus B10”, DBZ Deutsche Bauzeitschrift, vol. 3, 2014.
[8] W. McDonough, and M. Braungart, Cradle to Cradle: Remaking the way we make things, North Point Press, pp. 196, 2002.
[9] J. P. Petersen, and C. Roedel, “Smart Material House Woodcube”, IBA Hamburg, pp. 4-25, 2014.
[10] Reggeborgh Investment & Management, “Move in. to the future. The ICON building in Dortmund”, Reggeborgh Investment & Management, [Online] 2020 [Accessed 15 March 2020] Available at: https://icon-dortmund.de.
[11] K. Reich, “Wolfgang Priedemann – Die Fassade könnte noch mehr”, DBZ German construction magazine, vol. 8/9, p. 26, 2017 (in German).