# Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

# Graduation Plan: All tracks

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| Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest. |

The graduation plan consists of at least the following data/segments:

| **Personal information** | |
|---|---|
| Name | Shriya Balakrishnan |
| Student number | 5048664 |

| **Studio** | | |
|---|---|---|
| Name / Theme | Climate & Facade | |
| Main mentor | Regina Bokel | Building Physics and Services |
| Second mentor | Thaleia Konstantinou | Building Product Innovation |
| Argumentation of choice of the studio | Not Applicable for Building Technology master course. | |

| **Graduation project** | |
|---|---|
| Title of the graduation project | Refurbishment of an office building in the Netherlands using the Earth, Wind and Fire system. |
| **Goal** | |
| **Location:** | Provinciehuis Utrecht, The Netherlands |

**The posed problem:**

In the building sector, the non-domestic sector accounts for 13% of the total energy consumption out of which office building consume 50% of the energy (European Commission, 2020).
According to various statistics studied, the Netherlands and Europe as a whole is seeing poor performance in office buildings with respect to energy efficiency and thermal comfort in particular. There is an urgent need to rectify this problem by renovation or refurbishment, which will also lower the total energy consumption of the buildings by 5-6% (European Commission, 2020). The use of renewable energy resources is also negligible (only 7.8% of total energy consumption) for new constructions and for refurbishment. The Earth, Wind and Fire concept is based on the phenomenon of using the driving forces of nature to control the indoor climate of the buildings. It utilizes the environmental energy of earth mass, wind and sun to generate and supply energy throughout the building by eliminating the use of HVAC systems, thereby minimizing the total energy consumption of the building and providing a healthy and productive working environment (Bronsema, 2013). This concept can play a crucial role in improving the energy efficiency of office buildings that need to be refurbished and to achieve the ambitious 2050 goals set by the European Union and National Government.

**Research question:**

How are the design strategies derived from the Earth, Wind and Fire system, implemented in the refurbishment of an office building in The Netherlands in order to improve the energy performance?

**Design assignment in which these result:**

The findings from the literature study will be implemented on a case study. The case study building is Provinciehuis Utrecht which is an 85 m high office building dominating the skyline of east Utrecht. The case study will be a showcase of the elements of the EWF system attempting to prove the efficiency of the system as a climate machine and approaching one step closer to the ambitious 2050 goals set by the EU commission.

## Process

**Method description**

To answer the research question, the research process is divided into 3 stages: case study selection, analysis and final design.

**Selection of Case Study**

2 case studies were selected to make a comparative analysis on the basis of the building assessment criteria listed in the design strategies. Out of 2 case study buildings, one office building will be selected to implement the design strategies.

**Analysis**

The chosen case study will be refurbished using the EWF system which will primarily focus on analyzing the performance of Solar Chimney, solar facade and Climate Cascade. Various permutations and combinations will be considered for the location, shape and material of the Climate Cascade and Solar Chimney. These systems will be simulated using the basic excel calculation models developed by Bronsema (2013) and his team, along with dynamic modeling using Design Builder software. The simulations will focus on energy consumed by the system and external factors affecting the annual energy performance of the building for every design option.

The basic modeling process will include simple calculation models which will help in developing the first impressions of the feasibility and potential of the applied concept (Bronsema, 2013). The scientific and technical data required to perform these calculations will be derived from the MS Excel calculation developed by Bronsema (2013) and ABT B.V. The model consists of all the formulas derived from Installation Technology Manual (ISSO 2002), the Taschenbuch für Heizung + Klimatechnik, ASHRAE Handbooks Fundamentals (ASHRAE 2001) and HVAC Systems and Equipment (ASHRAE 2000) (Bronsema, 2013). The basic modeling will provide insight on the underlying phenomena of heat transfer and flow and how they work together. In order to validate the basic calculations, Design Builder software will be used. The excel calculations will be used for calculating and designing the Solar Chimney and

Climate Cascade under stationary conditions. In order to study the dynamic behavior and annual estimates of the energy performance of the EWF system, dynamic simulation model Design Builder will be used.
Once the simulations are conducted for various design options, the option which gives the best results, according to the design conditions which will be established before the simulations, will be selected for dynamic simulations.
For the second part of the simulation, additional factors like façade, space heating and cooling and other parameters will be evaluated by analyzing its impact on the overall energy consumption. The simulations will also focus on developing strategies to generate energy within the building and check if the building can achieve nearly zero energy consumption.

**Final design**
After deriving the final design solution, these results will be compared to the results of the current energy performance of the building i.e. without the application of EWF system. This comparison will determine the efficiency of the EWF system and whether the system can improve the energy performance of the building. Additionally, the building will be assessed to determine if the energy demands are met entirely by renewable resources (Paris proof).
The final design solution will contain detailed drawings (plans, sections, and elevations), detailed calculations and simulations of the Climate Cascade and Solar Chimney on the chosen case study building.

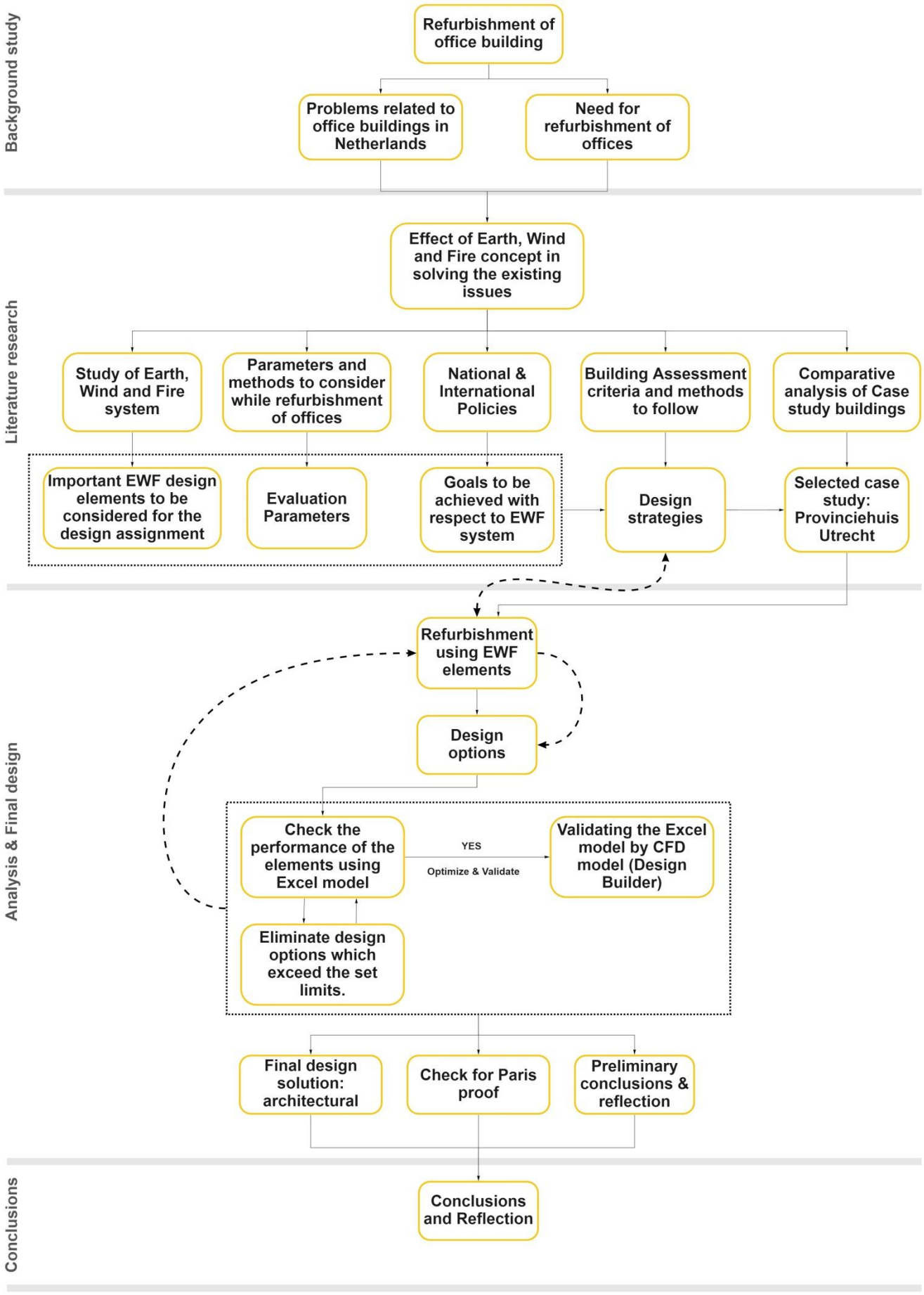


Figure 1: Basic Methodology scheme

| GRADUATION TIME PLANNING: P1-P5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Weekly Objectives | November | | | | December | | | | | January | | | | February | | | | March | | | | | April | | | | May | | | | June | | | | | |
| | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| Initial background study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **P1: Background Study** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Contextual study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Problem statement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reseatch Objectives | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Research Questions and Sub-questions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Research approach and methodology | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Analysis and study the Earth, Wind and Fire system | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Study the elements of the EWF system: Solar Chimney, Climate Cascade and Ventec roof. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Application of EWF system in Hotel Breeze, Amsterdam | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Study on office refurbishement and the evaluating parameters that correspond to office refurbishment. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Determine the goals set by BENG regualtions in order to achieve nearly Net Zero Energy Building with respect to EWF system. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Formulate the design challenges and opportunities in refurbishment of offices using EWF | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Explore design possibilities for the EWF elements using the 104 student submissions in the DSBT course. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Study the simulation methods used in evaluating the elemets of the EWF system. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| refurbished. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Define the strategies for implementing EWF in the chosen case study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Graduation Plan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **P2: Literature research** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Design the chosen building incorporating the EWF elements and abiding by the set design strategies. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Design options after implementing theEWF design strategies | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prepare a base simulation model according to the calculation methods determined in the literature study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Simulation Phase 1 : Identify the options which fit in the set nZEB goals and eliminate the rest. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **P3: Analysis** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Simulation Phase 2 : Optimise the options which nearly meet the nZEB goals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Simulation Phase 3: Select the design option which satisfies the nZEB requirements and maximum efficiency of 2 RBE's. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prepare the presentation drawings of the chosen case study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Preliminary conclusions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **P4: Final Design** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Final design | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Final conclusions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Final report and presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **P5: Conclusions & Reflection** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 1: Weekly objectives and organization of the research

## Literature and general practical preference


Al-Ashwal, N. T., & Hassan, A. S. (2017). The integration of day lighting with artificial lighting to enhance building energy performance. doi:10.1063/1.5005777

Baker, N. V. (2009). The handbook of sustainable refurbishment non-domestic buildings. London: Earthscan.

Balaras, C., Dascalaki, E., Droutsa, K., Micha, M., Kontyiannidis, S., & Argiriou, A. (2017). Energy use Intensities for Non-Residential Buildings. Proceedings of the 48th International HVAC&R Congress. doi:10.24094/kghk.017.48.1.369

Balaras, C., Droutsa, K., Argiriou, A., & Wittchen, K. (2002). Assessment of energy and natural resources conservation in office buildings using TOBUS. Energy and Buildings, 34(2), 135-153. doi:10.1016/s0378-7788(01)00107-4

Boer, A. (2020, October 05). Nieuwe monumenten 1970-2000: VSB/Fortis-gebouw in Rijnsweerd Noord. Retrieved January 07, 2021, from https://www.duic.nl/cultuur/nieuwe-monumenten-1970-2000-vsb-fortis-gebouw-in-rijnsweerd-noord/

Boerstra, A.C., Hoof, J.V., & Weele, A.M. (2015). A new hybrid thermal comfort guideline for the Netherlands: background and development. Architectural Science Review, 58, 24 - 34.

Bouwbesluit Online 2012. (n.d.). Retrieved January 06, 2021, from https://rijksoverheid.bouwbesluit.com/Inhoud

Brink, H., & Mobach, M. (2016). Quality and satisfaction of thermal comfort in Dutch offices. EuroFM Research Papers 2016. Retrieved January 5, 2021, from https://www.researchgate.net/publication/324363421

Bronsema, B. (2013, June 07). Earth, Wind & Fire: Natuurlijke Airconditioning. Retrieved December 20, 2020, from https://doi.org/10.4233/uuid:d181a9f2-2123-4de1-8856-cd7da74e8268

Bronsema, B., Bokel, R., Bruggema, H., Meerstadt, O., Quist, M., Spoel, W. V., . . . Veerman, J. (2018). Earth, Wind & Fire: The Evolution of an Innovation (1) – 'Earth': Natural ventilation and air conditioning using the Climate Cascade. The REHVA European HVAC Journal, 55(3), 65-74. Retrieved January 2, 2021, from https://www.rehva.eu/rehva-journal/chapter/earth-wind-fire-the-evolution-of-an-innovation-1-earth-natural-ventilation-and-air-conditioning-using-the-climate-cascade

Bronsema, B., Luijk, R. V., Swier, P., Veerman, J., & Vermeer, J. (2018). Natural air conditioning: What are we waiting for? The REHVA European HVAC Journal, 55(2), 21-25. Retrieved December 30, 2020, from https://www.rehva.eu/rehva-journal/chapter/natural-air-conditioning-what-are-we-waiting-for

Burton, S. (2013). Energy-efficient Office Refurbishment. doi:10.4324/9781315074344

De Souza, C. B., & Alsaadani, S. (2016, August 16). Introduction. In Thermal Zoning in Speculative Office Buildings: Discussing the Connections between Space Layout and inside Thermal Control. Retrieved December 28, 2020, from https://www.researchgate.net/publication/306203459

Demontage laagbouw Van Unnik. (2020, November 03). Retrieved January 07, 2021, from https://www.utrechtsciencepark.nl/nl/over-het-park/nieuws/demontage-laagbouw-van-unnik

Desideri, U., & Asdrubali, F. (2019). R 9 - Energy Efficiency in Building Renovation. In Handbook of energy efficiency in buildings: A life cycle approach (pp. 675-810). Oxford, United Kingdom: Butterworth-Heinemann is an imprint of Elsevier. doi:https://doi.org/10.1016/B978-0-12-812817-6.00042-5.

Drunen, I. V., & Hendriks, I. (2017). VSB HOOFDKANTOOR TE UTRECHT. Retrieved January 07, 2021, from https://docplayer.nl/39326652-Vsb-hoofdkantoor-te-utrecht.html

Dutch Green Building Council. (n.d.). Paris Proof Commitment. Retrieved December 29, 2020, from https://www.dgbc.nl/publicaties/paris-proof-commitment-36

Ebbert, T. (2010). Re-face: Refurbishment strategies for the technical improvement of office facades. Bochum: L'autor.

Energy use in buildings – contributions and considerations in urban systems. (2016, August 06). Retrieved December 18, 2020, from http://www.nef.org.uk/about-us/insights/energy-use-in-buildings-contributions-and-considerations-in-urban-systems

Energy, Climate change, Environment. (2020, May 19). Retrieved December 20, 2020, from https://ec.europa.eu/info/energy-climate-change-environment_en

European Union. (2018). DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency). Retrieved from https://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:32018L0844&from=EN

Fernbas. (2020, December 23). Energy performance of buildings directive - European Commission. Retrieved December 29, 2020, from https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

Heirbaut, J. (2019). Sustainable sleeping. De Ingenieur, (March), 22–25.

In focus: Energy efficiency in buildings. (2020, March 10). Retrieved December 18, 2020, from https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-feb-17_en

ISSO-KennisBank. Kennisbank.isso.nl. (2019). Retrieved 3 January 2021, from https://kennisbank.isso.nl/kennispaper/kennispaper-thermisch-comfort/2019/3.

Lan, L., Wargocki, P., & Lian, Z. (2012). Optimal thermal environment improves performance of office work. REHVA Journal, 49(1), 12-17.

Luchtfoto: Het provinciehuis in Utrecht flying holland.nl. (n.d.). Retrieved January 07, 2021, from https://www.flyingholland.nl/media/d520607b-4875-430e-aeca-dc1ec9293ee0-het-provinciehuis-in-utrecht

Open avond VVD Verkiezingsprogramma Provinciale Staten - VVD Montfoort. (2021). Retrieved 9 June 2021, from https://www.vvdmontfoort.nl/nieuws/9/2014/09/open_avond_vvd_verkiezingsprogramma_provinciale_staten

OZ Architect. (2019). Hotel Breeze Ijburg Amsterdam. Retrieved from OZ website: https://www.ozarchitect.nl/projects/hotel-breeze-ijburg/

Panev, S., Ossenbrink, H., Szabó, S., Bódis, K., & Saheb, Y. (2016). Energy renovation the trump card for the new start for Europe. Luxembourg: Publications Office.

Paris Agreement. (2015). Retrieved December 29, 2020, from https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Pearson, A. (2019). Force of nature – naturally ventilating Amsterdam's Breeze Hotel. Retrieved from CIBSE

Journal website: https://www.cibsejournal.com/case-studies/force-of-nature-naturally-ventilating-amsterdams-breeze-hotel/

Pepijntje. (2008, June 25). Willem C. van Unnikgebouw. Retrieved January 07, 2021, from https://commons.wikimedia.org/wiki/File:Willem_C._van_Unnikgebouw.JPG

Pivac, N., & Nižetić, S. (2017). Thermal comfort in office buildings: General issues and challenges. 1-4. Retrieved January 5, 2021, from https://www.researchgate.net/publication/315809782

Remøy, H., Dobbelsteen, A. V., Knaack, U., & Kwon, M. (2017). User-focused design factors of workspace for nearly zero energy office renovation: Findings from literature review. 24th Annual European Real Estate Society Conference. doi:10.15396/eres2017_275

Santamouris, M., Argiriou, A., Dascalaki, E., Balaras, C., & Gaglia, A. (1994). Energy characteristics and savings potential in office buildings. Solar Energy, 52(1), 59-66. doi:10.1016/0038-092x(94)90081-c

Smith, R. (2015). Directive 2010/41/EU of the European Parliament and of the Council of 7 July 2010. Core EU Legislation, 352-355. doi:10.1007/978-1-137-54482-7_33

Veen, L. V. (2020, July). The 'new' zero energy office building (Doctoral dissertation, Deft University of Technology, 2020). The Impact of Dutch Regulatory Changes on the Development of Energy Efficient Office Buildings., 24-29. Retrieved December 29, 2020, from http://resolver.tudelft.nl/uuid:a5771286-3c8e-41e4-9367-6035e2594748

Vijverberg, G. (2002). Renovation of offices: A survey of reasons, points of attention and obstacles in the Netherlands. Journal of Facilities Management, 1(1), 85-95. doi:10.1108/14725960310807791

Willem C. van Unnikgebouw. (2020, November 23). Retrieved January 07, 2021, from https://nl.wikipedia.org/wiki/Willem_C._van_Unnikgebouw

Wood, A., & Salib, R. (2012). Guide To Natural Ventilation in High Rise Office Buildings. Natural Ventilation in High-Rise Office Buildings: An Output of the CTBUH Sustainability Working Group, 17-20. doi:10.4324/9780203720042

(2020). Retrieved 15 December 2020, from https://brightspace.tudelft.nl/d2l/le/content/278591/Home