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To whom it may concern

Subject
Declaration concerning research findings on particulate matter removal in urban areas

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This is a declaration issued by Prof.dr.ir. Bert Blocken, the head of the research team *Urban Physics & Wind Engineering* at the Department of the Built Environment of Eindhoven University of Technology, the Netherlands, and also professor in *Computational Fluid Dynamics for the Built Environment* at the Department of Civil Engineering at KU Leuven University in Belgium, concerning obtained research results on the project “Lungs of the City of Eindhoven”.

The goal of the research project was to analyze the potential of the Aufero modules of the company ENS Technology, when installed in semi-enclosed parking garages of Eindhoven city center, to also remove particular matter (PM_{10} and $PM_{2.5}$) from the outdoor air (i.e. outside the parking garages) and thereby to improve the outdoor air quality in the surrounding urban area. Two virtual case studies were performed, in which modules were installed in 16 semi-enclosed parking garages (see figure 1):

- First case study with 1 Aufero module per 65 parking spots, yielding a total of 99 modules.
- Second case study with 6 Aufero modules per 65 parking spots, yielding a total of 594 modules.

The following main representative assumptions were made:

- The Aufero modules have a removal (collection) efficiency of 70% for PM_{10}.
- The atmosphere exhibits neutral stratification.
- The potential wind speed at 10 m height is 1 m/s.
- The wind direction is south-east.
- The upstream (background) PM_{10} concentration is 17.3 $\mu g/m^3$ (from nearby measurement station Veldhoven)

The Aufero modules were virtually inserted in the parking garages of an extensive Computational Fluid Dynamics (CFD) model of Eindhoven city center. This model is shown in figure 2 (whole model) and parts in figures 3 and 4.

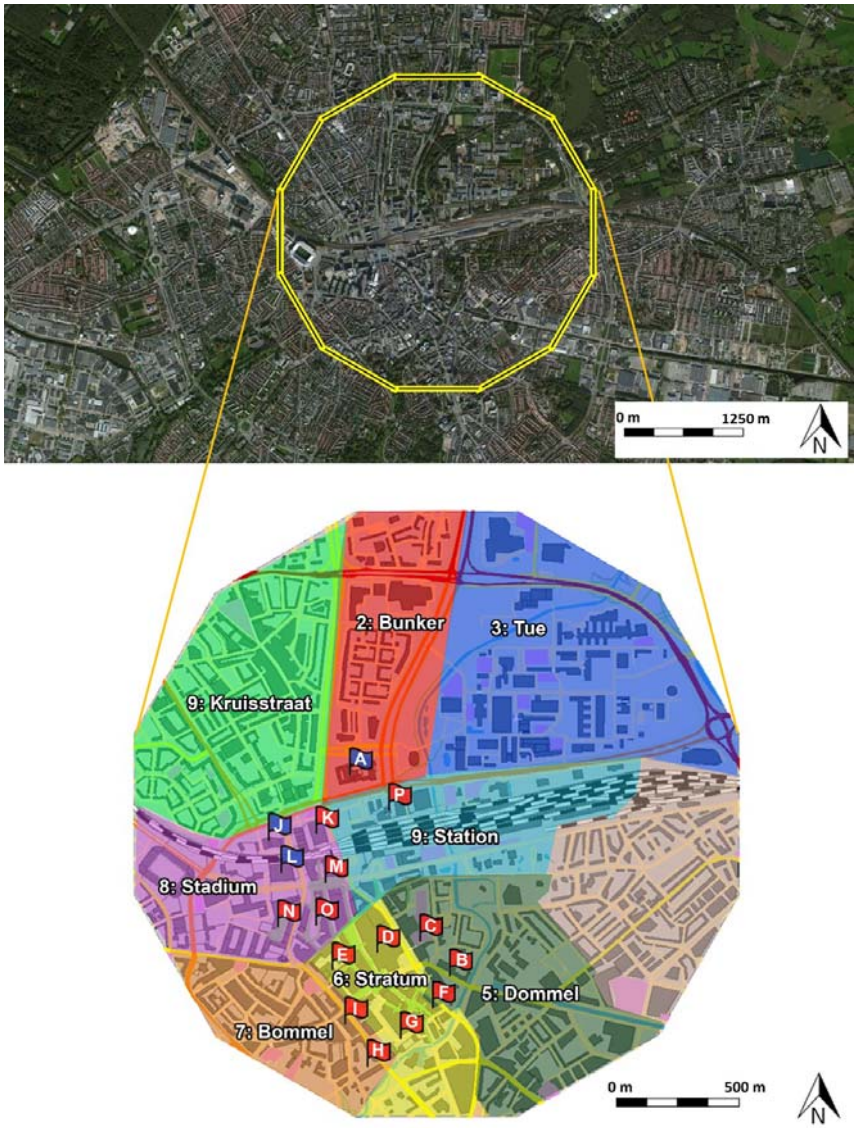

Figure 1. Location of 16 parking garages (A – P) for case study in Eindhoven city center.

Figure 2. CFD model of Eindhoven city center: full view.

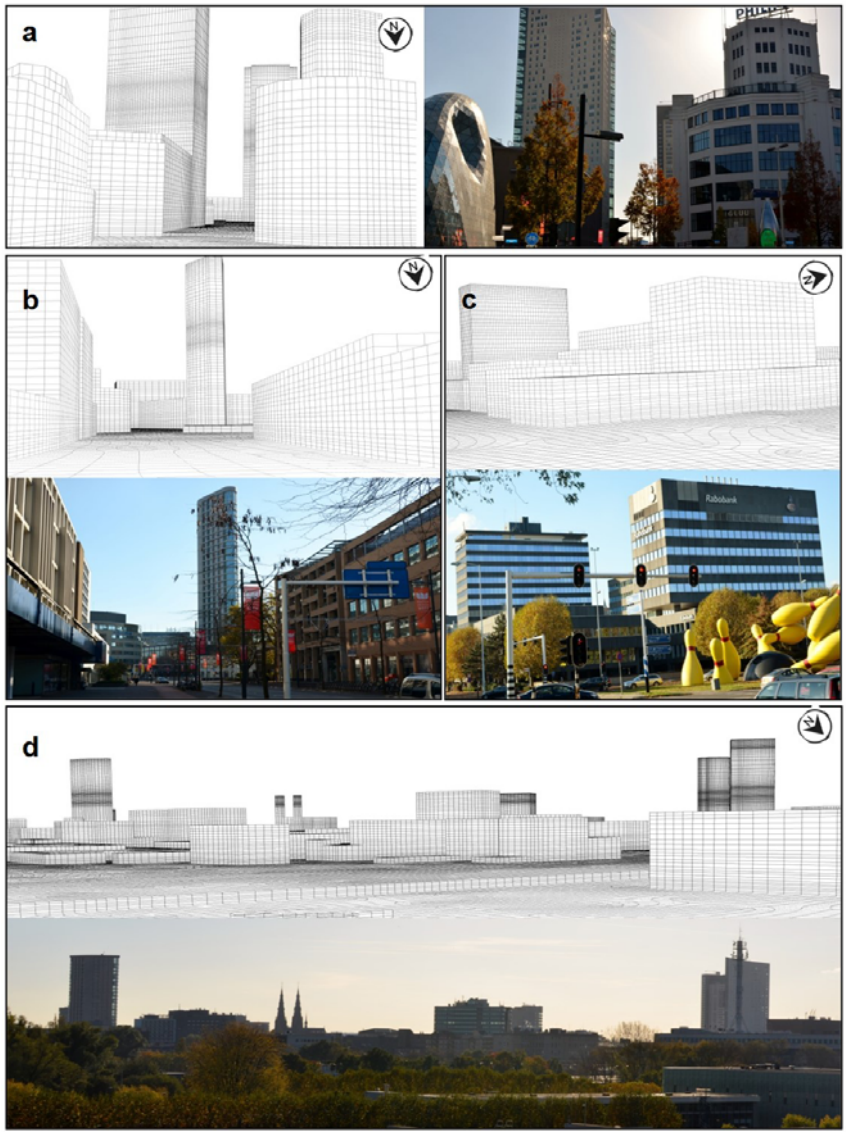

Figure 3. CFD model of Eindhoven city center: detailed view.

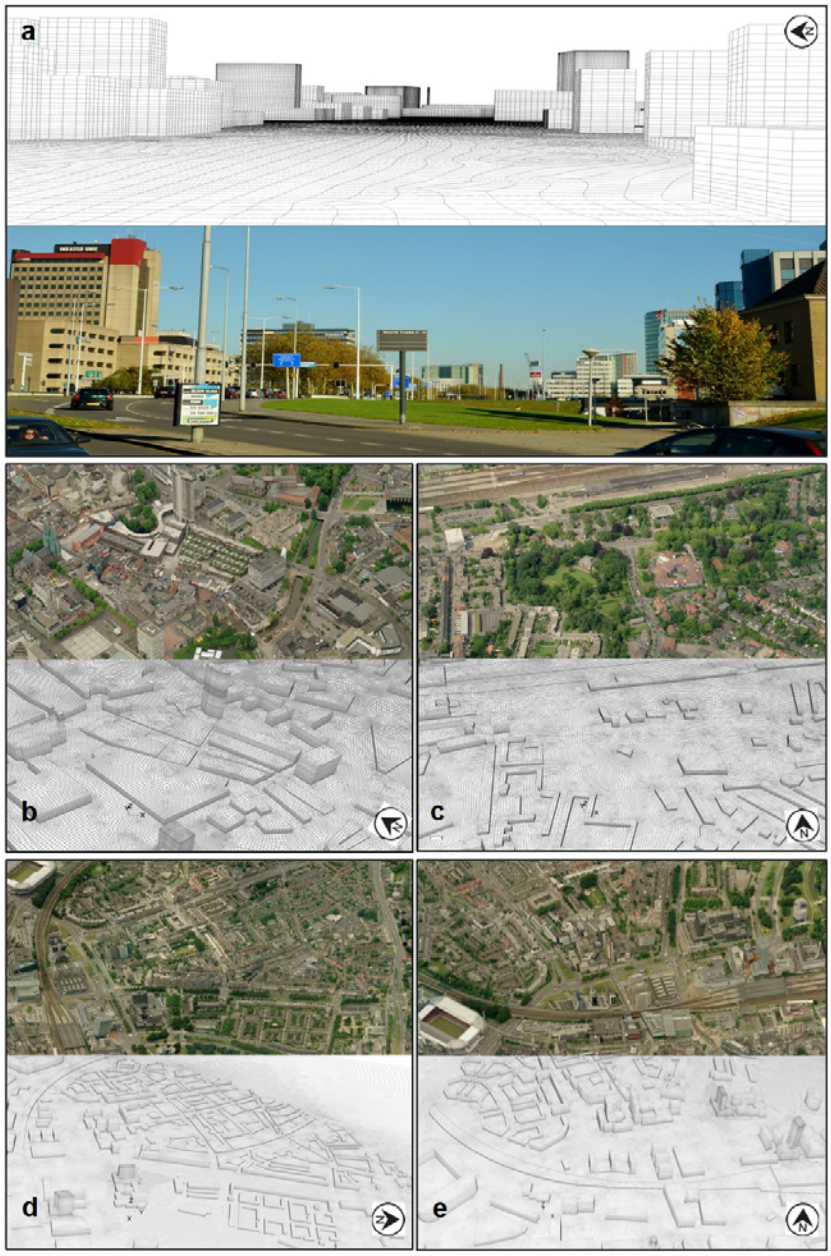

Figure 4. CFD model of Eindhoven city center: detailed view.

Next, actual data of traffic intensity, traffic exhaust, parking garage use and background concentrations of PM were used to provide pollution boundary conditions. The simulations were run for meteorological conditions typical of a day with substantial air pollution, with a reference wind speed at 10 m height of 1 m/s and wind direction from south-east. The simulations were performed based on the Reynolds-averaged Navier-Stokes equations with the realizable k-ε module for closure, and near-wall modelling by standard wall functions with appropriate roughness modifications as developed by Cebeci and Bradshaw (1977) and with sand-grain roughness values as obtained by Blocken et al. (2007). Simulations were performed either with or without Aufero modules installed in the parking garages.

Figure 5 below shows on the left side the results of the simulations without Aufero modules and on the right side the results with the 594 Aufero modules installed. The figures show the contours of PM_{10} concentration in a horizontal plane at 1.75 m height (walking height), where the red color indicate the highest concentrations and the blue color the lowest concentrations. It is clear that the Aufero modules provide strong reductions in PM_{10} in some of the outdoor streets surrounding the parking garages, and that this reduction is transported downstream with the wind. Also in the wider downstream area, even 1 km downstream of the parking garages, still very substantial reductions are found.

Figure 6 shows the percentage reductions in PM_{10} concentration that are obtained either by inserting 99 Aufero modules (left column) or by inserting 594 Aufero modules (right column) in the parking garages. It is clear that in a very large area, the reductions are higher than 10%, and go up to 50% and even slightly more. Note that the colorbars do not indicate the highest reductions, these colorbars are cut at either -10% or -50%.

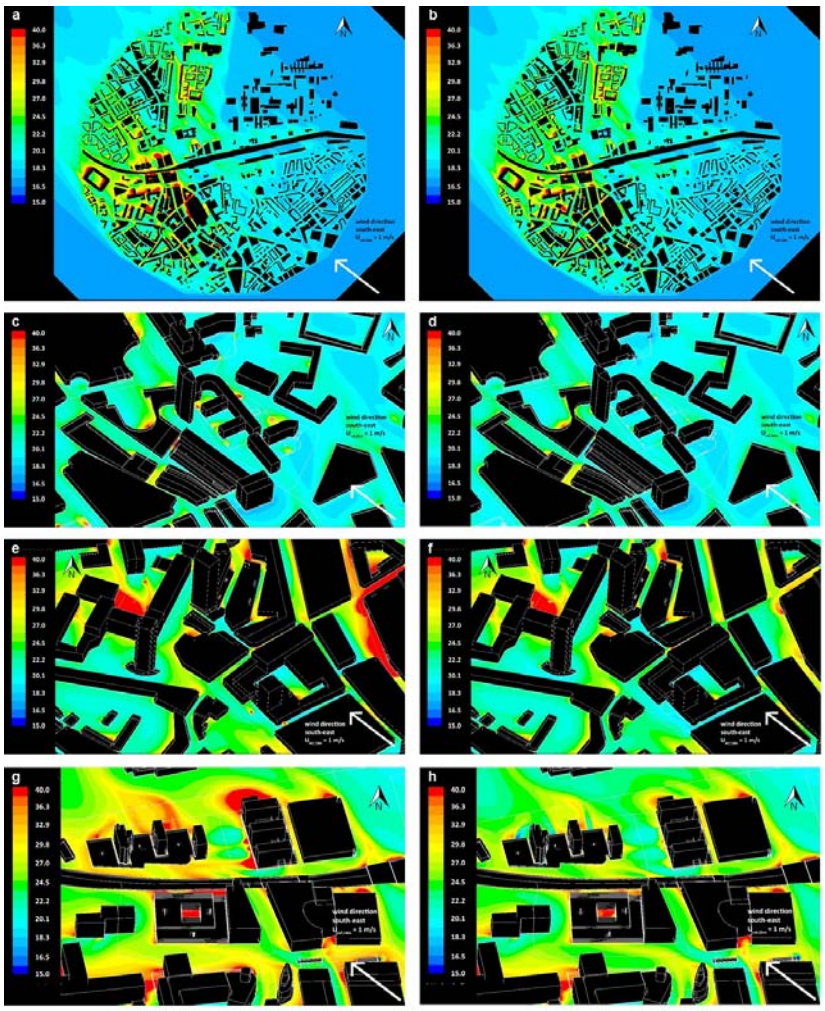

Figure 5. Results of CFD simulations. Contours of PM_{10} concentration in a horizontal plane at 1.75 m height (walking height), where the red color indicates the highest concentrations and the blue color the lowest concentrations. Left: without Aufero modules, right: with 594 Aufero modules in parking garages.

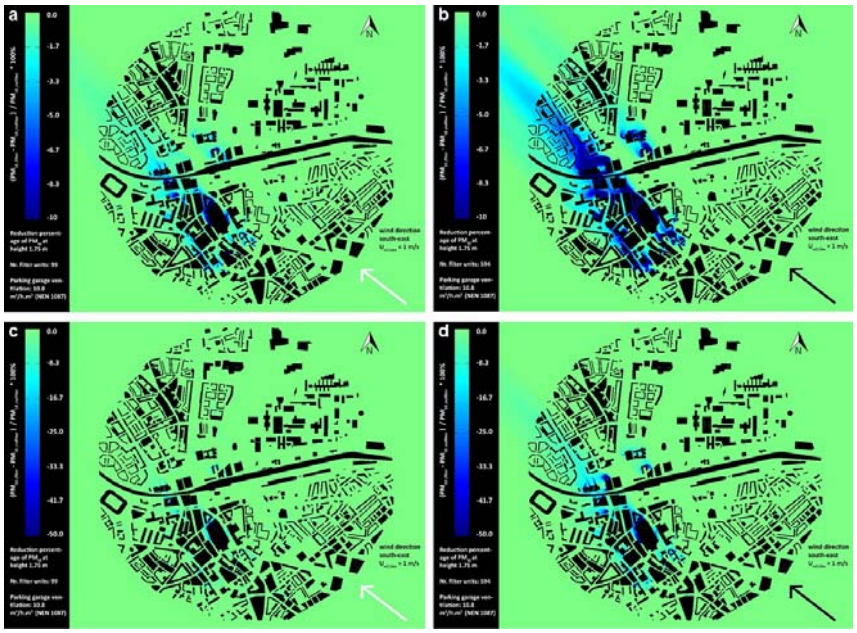

Figure 6. Results of CFD simulations. Contours of PM_{10} concentration reduction (percentage) in a horizontal plane at 1.75 m height (walking height). (a) With 99 Aufero modules, colorbar 0 to -10%; (b) With 594 Aufero modules, colorbar 0 to -10%; (c) With 99 Aufero modules, colorbar 0 to -50%; (d) With 594 Aufero modules, colorbar 0 to -50%. Note that the colorbars do not indicate the highest reductions, these colorbars are cut at either -10% or -50%.

Currently, the researchers are evaluating the effects for lower wind speed (less than 1 m/s), which is more representative for high pollution episodes, where the effects are expected to be much larger. The research team has also written and submitted a scientific article about this work for publication in an international peer-reviewed journal.

Conclusions:

- Aufero modules installed in parking garages do not only purify the indoor air inside these parking garages, but also the outdoor air in the surrounding streets, and even over a wide area downstream of the parking garages.
- Aufero modules can be used to actively purify city air and therefore to contribute to solve the fine dust problem in cities worldwide.

Comments:

- Aufero modules do not need to be installed in parking garages to be effective in removing fine dust from the air. They can also be placed in busy streets, in outdoor parking spaces, in tunnels, under bridges, etc. In this case, it is very important to apply high-quality CFD simulations to determine the best and most effective locations in the city for placement of the modules.
- The research team can work together with the company ENS Technology to develop city models – as done for Eindhoven – for any city worldwide, to:
    - 1) Determine the best positions in the city for placement of Aufero modules

- 2) Predict the effect/efficiency of the Aufero modules in cleaning the outdoor air.

Finally, it should be noted that the improvement of the outdoor air quality will generally also lead to the improvement of the indoor air quality as mostly outdoor air is used for building ventilation.

Please do not hesitate to contact me if further information is needed.

Yours sincerely

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