CFD-based Wind Pressure Coefficients-integrated Building Energy Modeling Workflow

1. Background

Today, building energy modeling (BEM) tools are largely being employed by practitioners for informed design decision-making. They are largely utilized for evaluating climate responsiveness and determining energy saving potential of measures to a building design. Notably, present-day BEM tools possess limitation in considering local wind affected by surrounding urban form. Popularly used BEM tool – the EnergyPlus (E+) uses airflow network (AFN) model to compute wind pressure coefficient (WPC) for individual building surfaces. These WPCs are key for computing the natural ventilation, infiltration and exfiltration of buildings. However, the default WPC calculation of E+ is limited to rectangular low-rise and high-rise buildings. This shortcoming can overestimate or undermine the potential of architectural measures, like natural ventilation.

Computational Fluid Dynamics (CFD) tools, like OpenFoam, are usually employed for simulating WPCs. Traditionally, the WPCs from OpenFoam are manually incorporated in E+ models to perform CFD-based WPCs-integrated BEM. This approach becomes more challenging with the increase in complexity of form and number of zones in building. Currently, the computational design platform, Rhinoceros-Grasshopper (Rhino-GH) encompasses both E+ plugin – Honeybee (HB) and OpenFoam plugin - EDDY3D for modelers to perform BEM and CFD modeling and simulation together. However, the WPCs from EDDY3D still need to be integrated into E+ models manually.

To overcome this issue, a new Rhino-GH workflow is developed using some custom scripted, EDDY3D, and HB components. This manual explains the new workflow in three parts: 1. Inputs, 2. Modeling, and 3. Simulation. The logic inscribed in the custom component developed in this workflow is also covered in the following section. Access to code of the custom components is restricted for academic reasons. In future, authors will reveal the password to the clusters. Users need to install Ladybug tools and EDDY3D to operationalize this workflow in their systems, along with Rhinoceros.

2. Inputs

2.1 Mandatory inputs

The first set of mandatory inputs needed for the workflow are the geometry details. As shown in **Figure 1** below, the geometry of neighboring buildings and other obstructions that interfere with the wind exposure of the subject building needs to be provided in component name “Context” in 00_Inputs section. Even the balconies or shades of subject buildings need to be supplied in the Context component. The boundary representation objects (BREP) of Rhino-GH representing the rooms of subject building needs to be assigned to a component “Main” in 00_Inputs section. Lastly, the directory path to store outputs is to be supplied to “dir” panel (Input 03 in Figure 1) in same section.

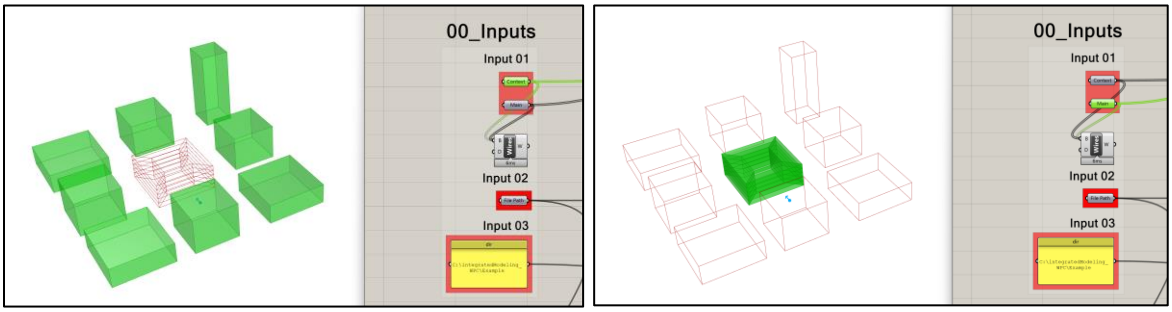

Figure 1 "00_Inputs" section in the workflow

2.2 Optional inputs

The EnergyPlus weather file (EPW) file can be selected using "EPW File Path" component (Input 02 in Figure 01), which is optional. If provided, the cluster created with native Ladybug (LB) and custom scripted components calculate the wind speeds and their duration out of 8760 hours. As shown in Figure 2, 0.5 value provided using "% of 8760" slider allows the cluster to recognize the first few wind speeds with highest durations covering nearly 50% of the 8760 hours. This can help users to compute duration averaged wind speed that can be supplied as reference wind speed for CFD modeling.

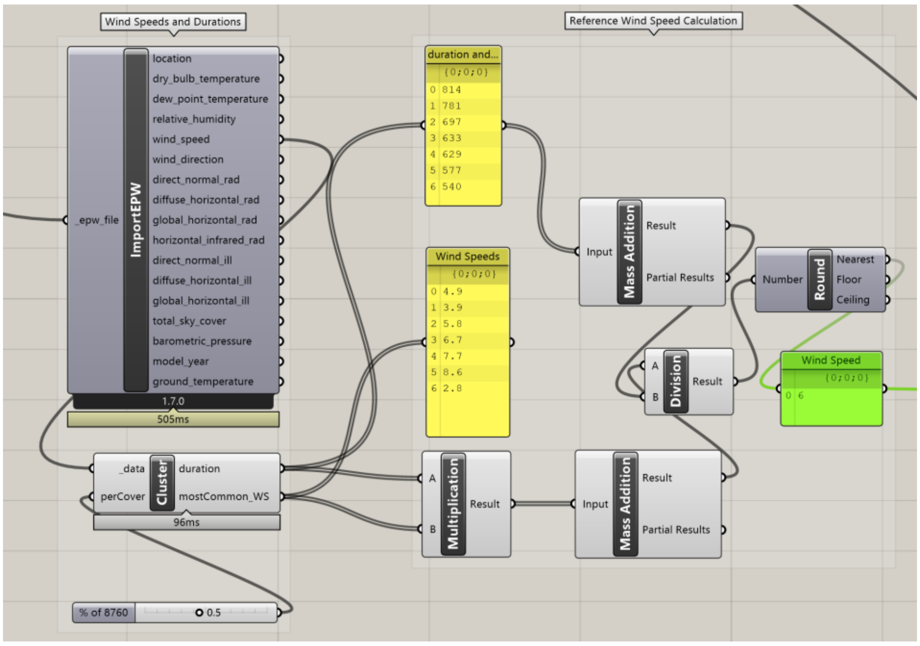

Figure 2 Recognition of potential wind speeds and their durations for computing reference wind speed for CFD.

3. Modeling

3.1 Building Energy Modeling

This is part of workflow constructed using native Honeybee (HB) components of LB tools. The users can alter this part of the workflow as they need, with few restrictions. This first one is to make sure that the apertures are set operable when assigned. The second important aspect is window opening and ventilation control details are also assigned. Finally, do not disturb the output wires connected to "Model" component of HB which is circled in **Figure 3**. This workflow opted LB tools version 1.8 and there should be no issue for users using non-legacy version of LB tools. In any case, the “LB Sync Grasshopper File” should mostly resolve the version issue.

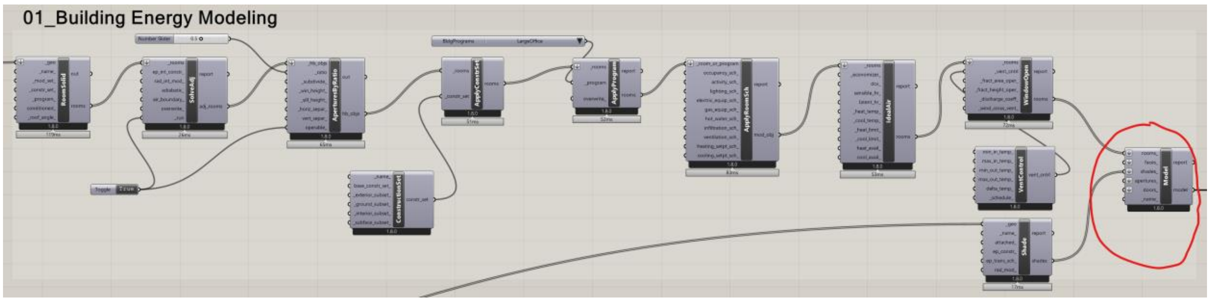

Figure 3 *The building energy modeling part of workflow with "Model" component circled.*

3.2 CFD Modeling

Users can use the duration averaged wind speed or custom reference wind speed for computing WPCs using EDDY3D standard template workflow, as shown in **Figure 4**. Currently, the list of wind directions to which WPCs are being computed should not be altered. The logic of the workflow is set to working for only eight wind directions.

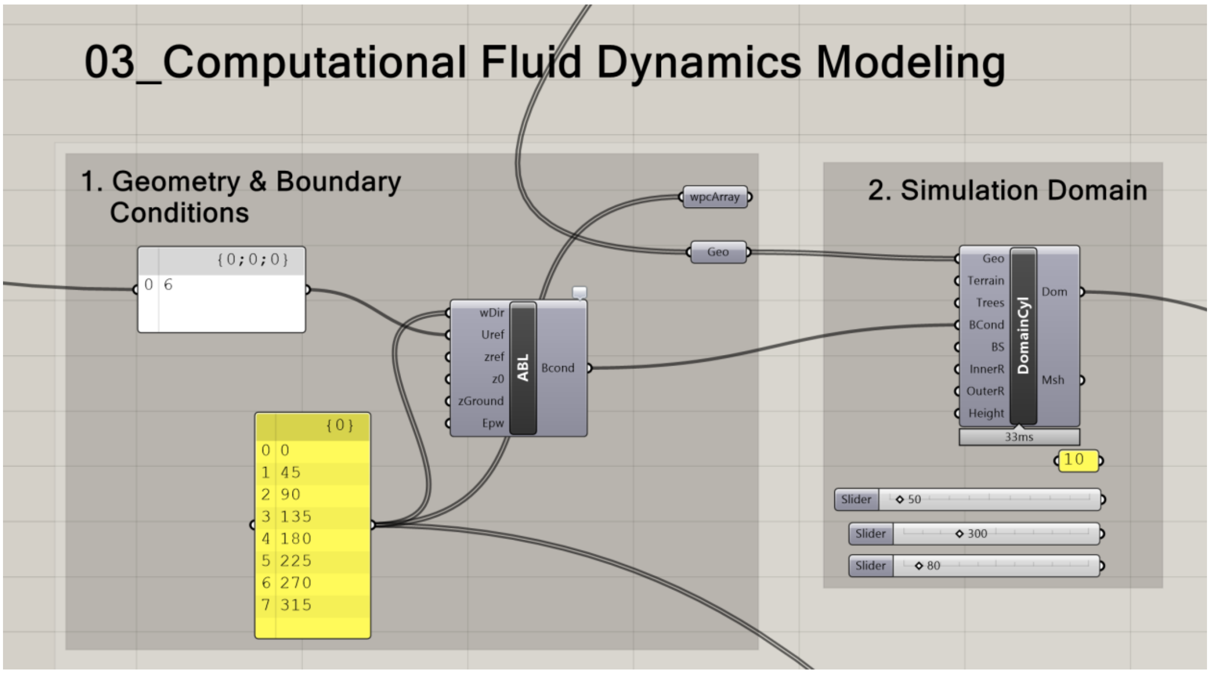

Figure 4 *The panel is white is for reference wind speed, while the one in yellow for wind directions to which WPCs are computed.*

The geometry and probes needed to simulate and extract WPCs specific building external walls and windows are automatically generated using custom components. In 02_WPCs Integration section the “hbObj_cfdMesh_epInputs” cluster component considers HB model to produce list of probes and other outputs that are specific to subject model. To improve the resolution of probes per surface the grid size on the component can be reduced further. The “02_WPCs Integration” is the second custom component cluster that generates the geometry for CFD simulation considering HB model. Depending on level of expertise the users can change the inputs of CFD modeling except for those mentioned above. Users also need to note that by default 1000 iterations were set for computing WPCs, which users can override if required residual convergence can be achieved with less or more iterations.

4. Simulation

4.1 CFD

Firstly, CFD simulation is needed ahead of building energy simulation as WPCs from EDDY3D "VisProbes" are needed. As shown in **Figure 5**, the button "meshingSim_Button" (Run 1) needs to be clicked first. A command prompt shell will appear that starts CFD simulation and wait till it closes by itself. Usually, it takes a few hours to a day, depending on the configuration of user's system and size of the model. Please click on button "probing_Button" (Run 2) after simulation is done, which extracts WPCs data. Note that it takes more time if the probes are more than 5000.

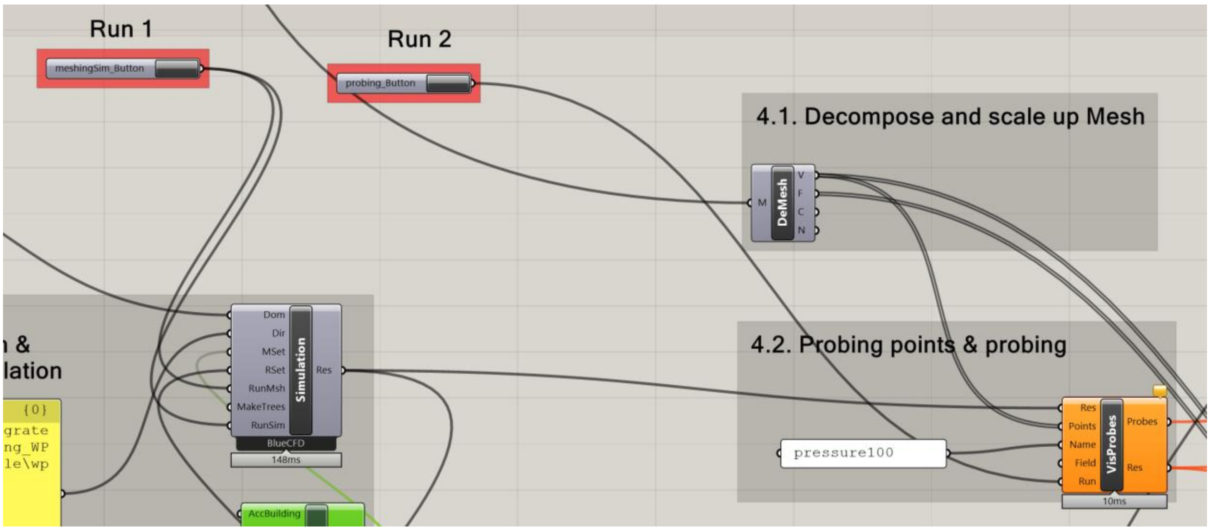

Figure 5 *Buttons to run and probe the WPCs.*

4.2 Energy

Once WPCs data is available, the "EP_AFN_simpleWindow_Crack" cluster component generates input data file (IDF) strings. This component mainly scripts the AFN Simple Window Opening and its related EP objects needed for simulating energy performance. If aware, users can alter some of the FAN modeling inputs to override the defaults. The description of the inputs is taken from EP Input Output reference guide for users' convenience. This component computes WPC for each surface by averaging the probe values that is part of surface. A cluster component "vis_processor" is also provided for users to visualize the WPC computed by EDDY3D for individual surface in each orientation. This can be compared with the default visualization facilitated by EDDy3D.

Software development kit (SDK) of Ladybug tools is largely used to develop these components. Although the IDF strings can be read using native "Panel" component, it is not recommended as it can freeze the user's system if external wall and window surfaces are large in number. As shown in **Figure 6**, HB components for standard simulation with HB AFN component and WPCs integrated simulation with HB Model component incorporated with IDF strings are provided. This is for users to observe variation in energy performance results. Users can further expand on this part based on their requirement. Kindly note that this workflow has been tested on very few models and few users may experience. However, we wish to hear it and solve it through all possible communication modes.

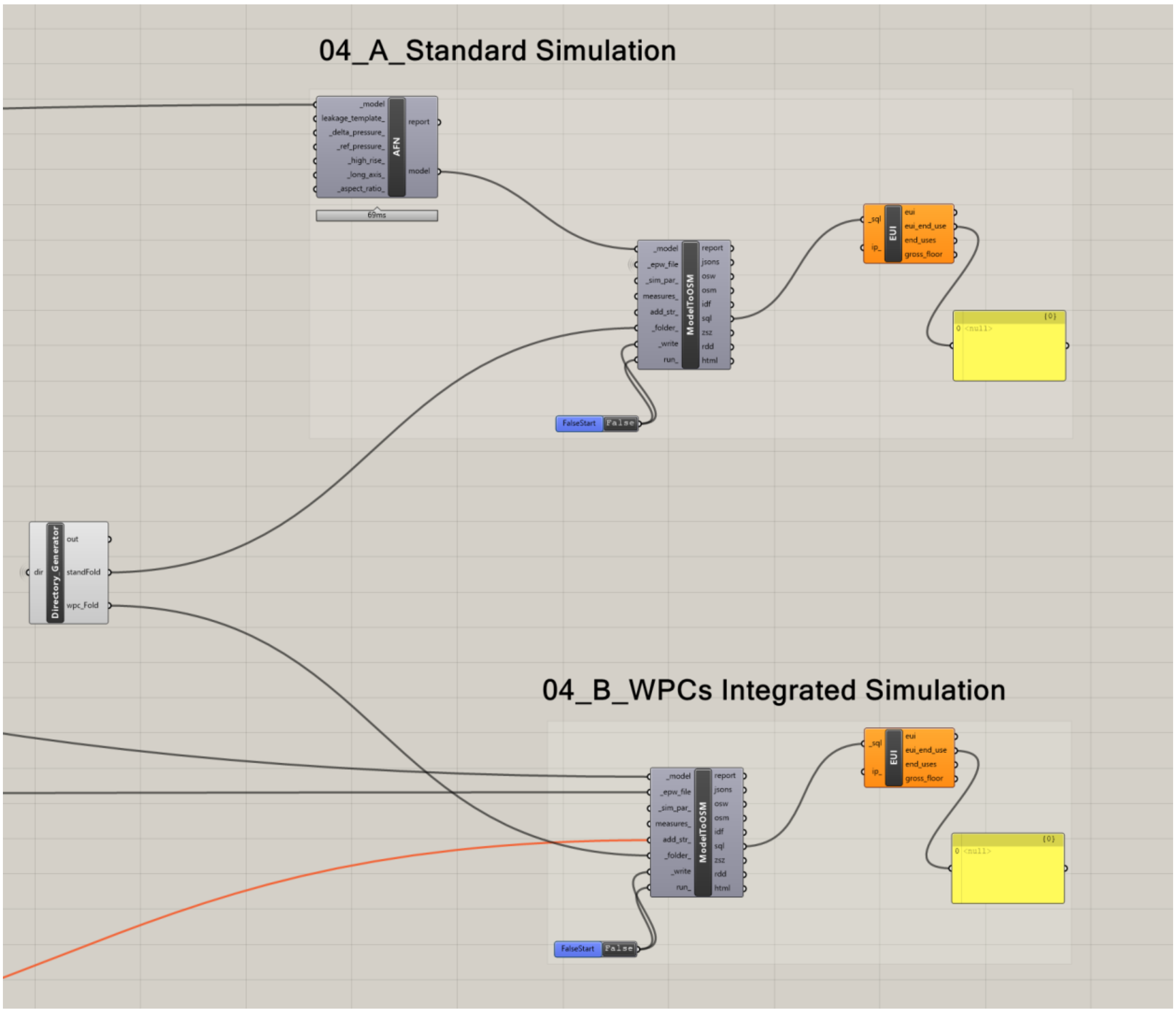

Figure 6 Standard simulation is with native HB AFN component, while WPCs integrated simulation is with IDF strings generated.

5. Reference

We kindly request the users to read and cite our open-access article "[Parametric Integration of CFD-based Wind Pressure Coefficients into Building Energy Models: A Novel Workflow]", which is the basis of this workflow development. The citation along with DOI is provided below for your reference. Although the article used AFN detailed opening component, necessary changes are made in this workflow, considering recent advancements in EP. The novelty of generating design-specific IDF strings for HB models between the published study and workflow remains same. Users appreciation in the form of citations will be instrumental for us to apply to advance existing and develop new workflows for both academic and industry use.

Citation:

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6. Acknowledgements

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