LowDown Showdown Energy Modelling Competition 2016

Team DeeBees win the ASHRAE "Best Energy Performance" award at SimBuild 2016 using DesignBuilder

Combine a great team with great software and the end result is an award-winning project! Following directly on from Team DesignBuilder's success in 2015 with the "Best Innovative Workflow" award, Team DeeBees used DesignBuilder in the 2016 ASHRAE competition to design a 40,000 Sq Ft net-zero energy healthcare building in Nebraska. Here's an overview of how we did it...

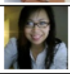
The DeeBees being presented with the ASHRAE "Best Energy Performance" award

[Watch the Recording of a Webinar explaining the prize-winning design process]

Background

The August 2016 ASHRAE-IBPSA US SimBuild Building Performance Modeling Conference ran a competition to design a 40,000 Sq Ft "new-build" healthcare facility in Omaha, with the aim of reaching net-zero energy consumption. Nine teams entered the competition, each using different energy modelling software. We all started with a modified ASHRAE 90.1 baseline healthcare building and a set of rules devised by the committee and had the task of creating a proposed building from the baseline building provided. Each team presented their projects on one afternoon to the full conference and the audience voted on 5 award categories following a Q&A panel session.

Team DeeBees contained a great mix of talent from a broad spectrum of backgrounds. The team was captained by Jim Dirkes from Building Performance Team and coached by Dave Cocking from DesignBuilder. Here's the "team sheet":

Name	Team Role	Company
Aaron Boranian 	Energy modeller	Big Ladder Software
Dave Cocking 	Coach	DesignBuilder Software
James Dirkes 	Engineer/Captain	Building Performance Team
Chitra Nambiar 	Architect	Noresco
Yung Nguyen 	Engineer	DNV GL
Sukreet Singh 	Architect	Cunningham Group
Weili Xu 	Energy modeller	Carnegie Mellon University

To make the competition more realistic Jim introduced an Owner Program Requirement (OPR) document. The OPR required the team to: (1) explore a prototype outpatient facility which improves energy performance over their standard practice (i.e. ASHRAE's baseline) by at least 30%; and (2) the prototype facility must be cost-effective AND duplicable. This meant the design must be flexible and scalable depending on location, climate, site footprint, impact of adjacent buildings etc.

Concept-stage design

The energy and enthusiasm in the team was fantastic…there was a clear desire to go beyond "the norm" and push boundaries. We decided early on that our focus would be on "health and wellbeing" which is an emerging area of simulation and design with standards such as WELL. We were also mindful that there are less tangible but nevertheless important cost benefits of providing healthy environments. It can help to improve productivity and reduce absenteeism etc. in staff, and a calming environment improves the overall experience and recovery time for patients. This seemed like a win-win to us!

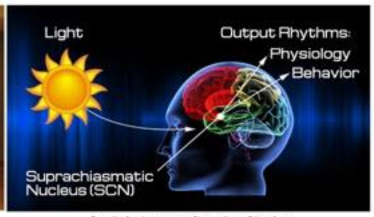
Indoor spaces overlooking courtyard

Green Overlook from Treatment Rooms

Dashboard & Interior Green Wall

Indoor spaces overlooking outdoor

Tunable LEDs



Daylight Impacts Circadian Rhythm

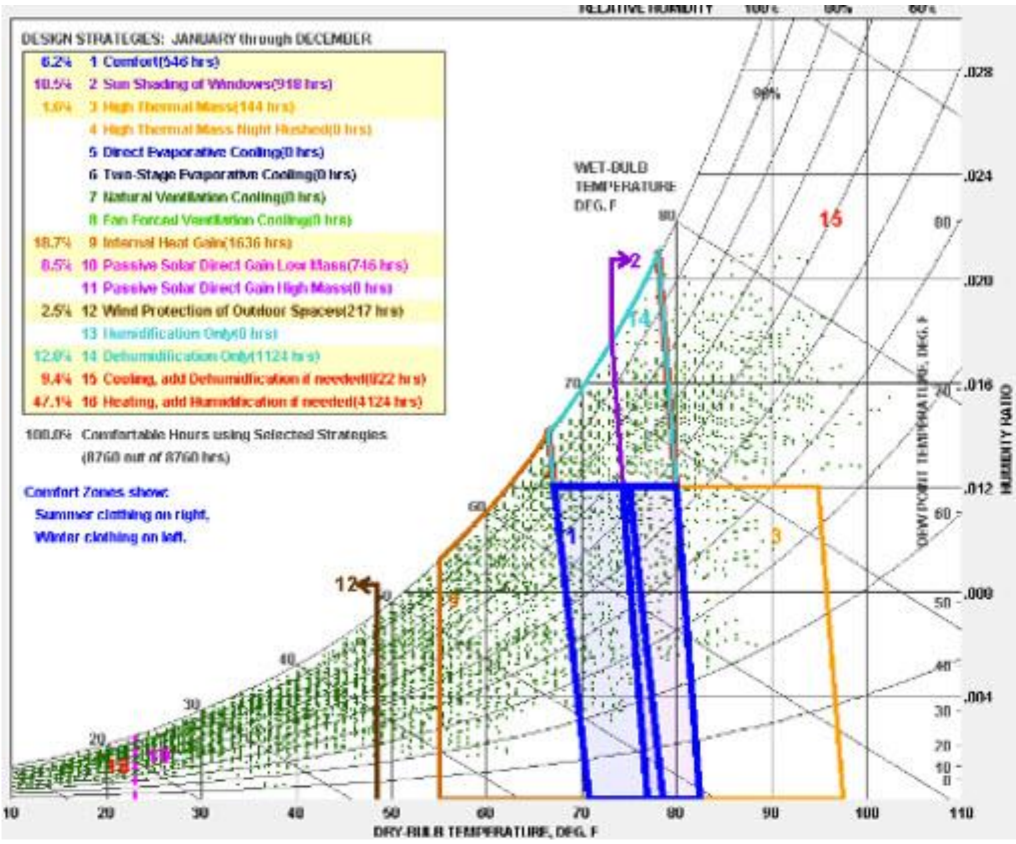
The architects' health and wellbeing design strategy…a room with a view!

Health and wellbeing metrics were assessed through DesignBuilder's fully-integrated toolset that includes the ability to simulate energy and comfort performance, HVAC systems and loads using EnergyPlus, passive solutions such as natural ventilation cooling, daylighting using Radiance, costing and CFD. This meant the team could build a single model in DesignBuilder and run a variety of different analyses to minimise modelling time and effort.

The health and wellbeing focus made daylight availability, "sky views" and views to green planting and the natural environment a key consideration that would heavily influence the building form. The team architects, Sukreet and Chitra, were instrumental in bringing that concept to life through a series of initial sketch designs to optimise the building form and internal layout. Their primary aim was to ensure that all occupied rooms were well daylit with a view to the outside, and one particular image (below) that really sold this concept to the team was from a similar project that Sukreet had recently been involved in. How many MRI or similar clinical rooms have you experienced with a view like this?

A clinical "room with a view"…provides a "calming" patient experience

The team initially considered maximising the use of passive strategies such as natural ventilation cooling (or at least a hybrid mixed-mode solution), so Aaron did some climate analysis using the Climate Consultant tool.

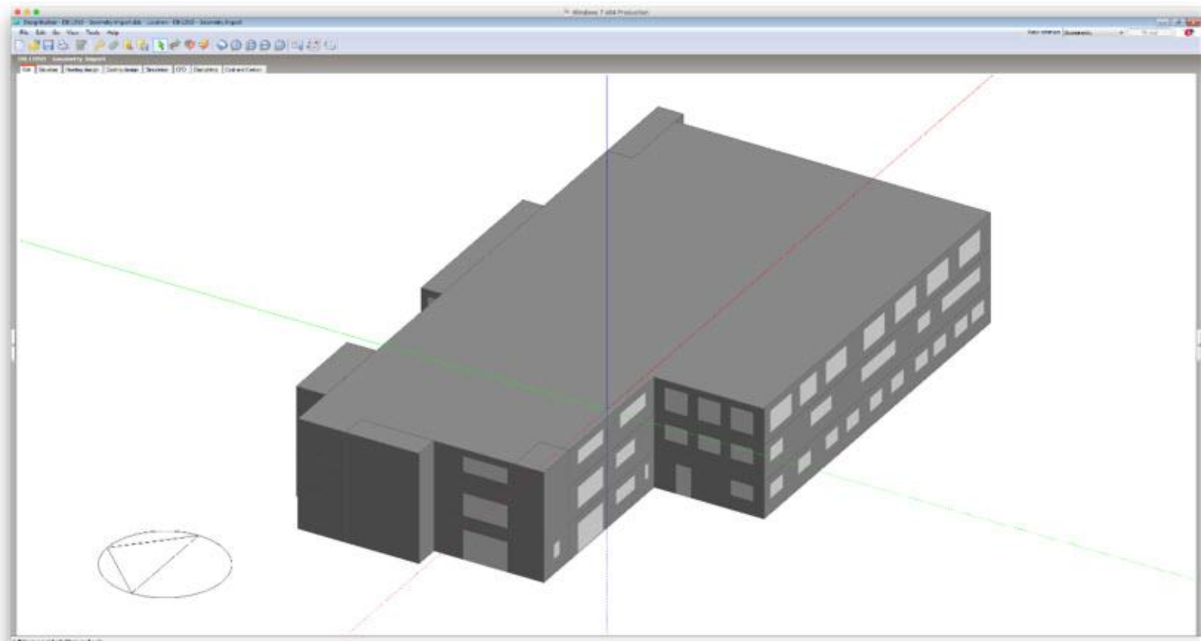


Early-stage climate analysis

This indicated that natural ventilation was not an appropriate solution for this building type in the Omaha climate, which helped feed into decisions about our optimal building form, layout and HVAC strategy.

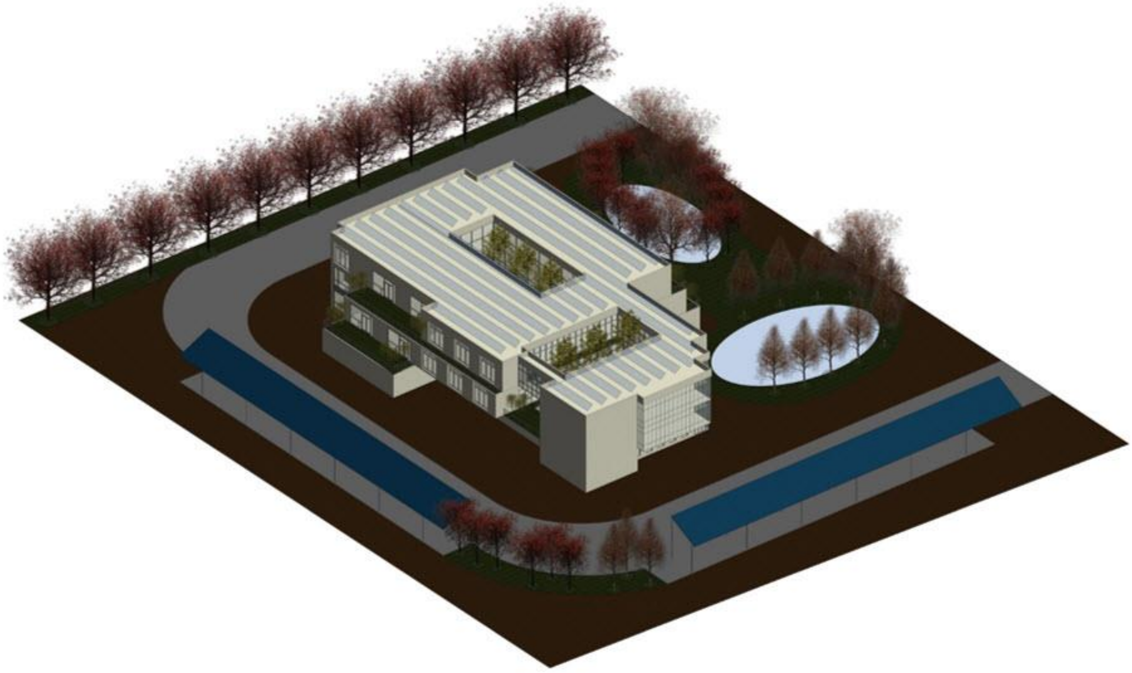
The project was a little unusual in that it started with the baseline, rather than generating the baseline from the proposed building. That was a real shame (for DesignBuilder at least) as it didn't give the team the opportunity to use DesignBuilder's automated baseline building and HVAC generation tools as part of the project!

The baseline provided by ASHRAE was a modified version of the US PNNL example healthcare building, for which an EnergyPlus idf file was available. That was imported seamlessly into DesignBuilder as gbXML via OpenStudio (see below – DB will soon have the direct idf import capability). With the geometry (building form and thermal zones) in place, Weili input the relevant data to create the baseline building according to competition requirements.

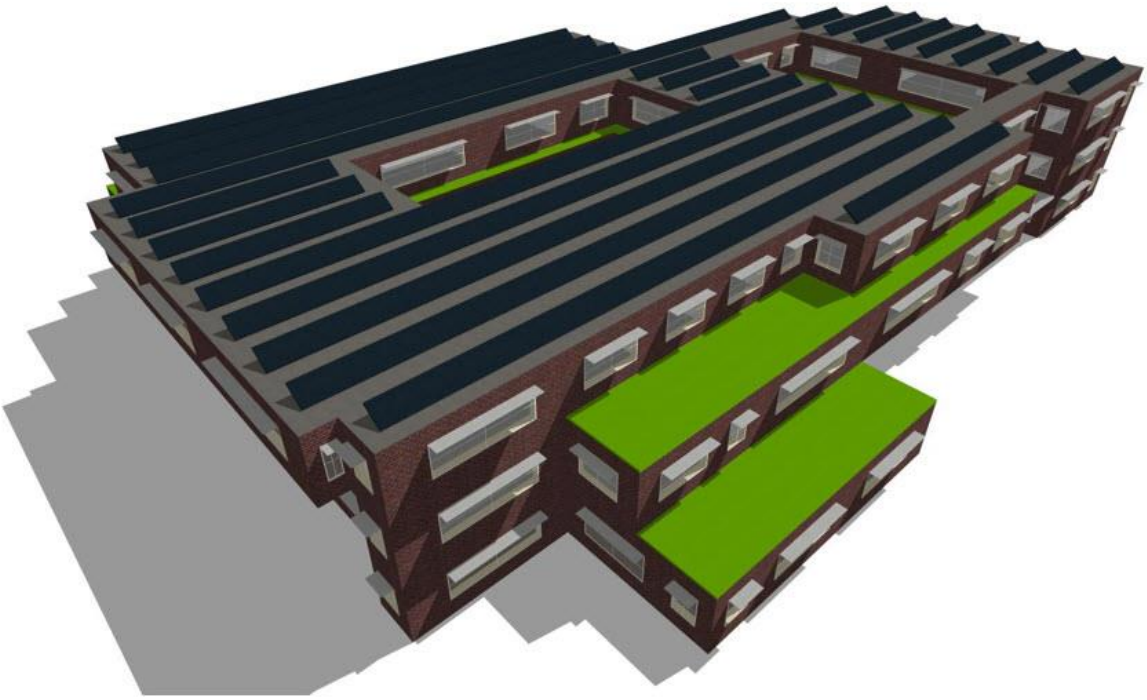


The PNNL idf data imported seamlessly into DesignBuilder as a gbXML file

Weili, Sukreet and Chitra then created the proposed building layout, which was an improvement on the baseline layout to make best use of daylight following the initial architectural analysis.



The architect's (and owner/client) vision of the proposed building for this site



Initial pre-optimisation iteration of proposed building

The image of the initial proposed building shows the intentional use of courtyards and tiered facades with green planting to maximise daylight and soothing views. The competition rules allowed 10,000 Sq Ft of rooftop PV. We could only fit around 5,000 Sq Ft of PV on our roof given the access requirements around the panels for maintenance and snow clearance etc. We added the remaining 5,000 Sq Ft later as car park shading structures.

Early-stage design

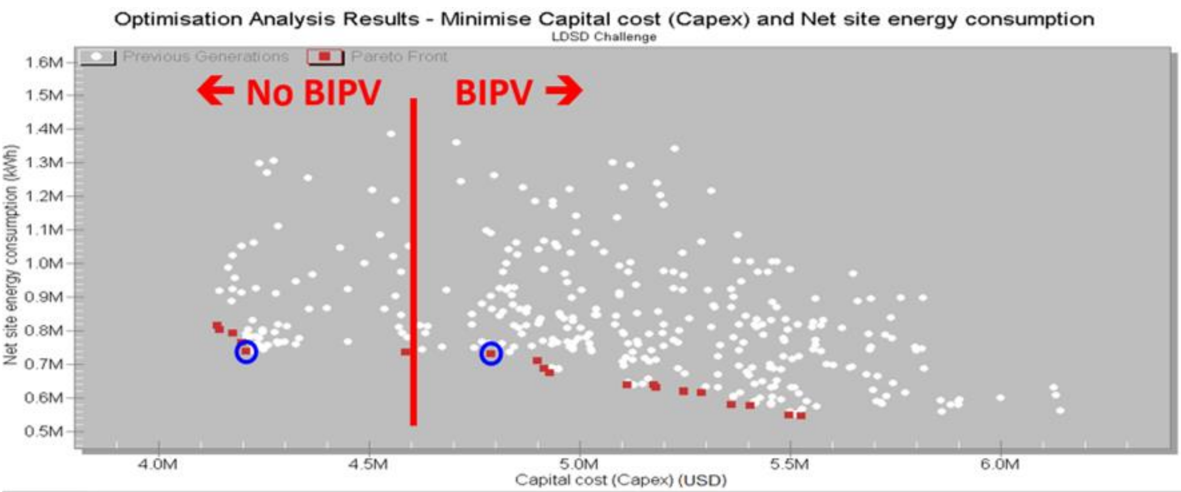
Having confirmed the building form and internal layout, Weili and Aaron started work on a cost-benefit study which focused on optimising the thermal envelope to minimise heating and cooling loads. Prior to setting up the optimisation study they worked independently to set up a range of different templates for different variables, and then imported them into the "master" model for optimisation. The team used DesignBuilder templates extensively in this way to enable parallel working with full control over what was imported into the master model.

You can't escape construction and operation costs (Capex and Opex) in real-world projects, which are often very high on the project meeting agenda. So the team decided it was essential to include cost and the implications of our design choices on both Capex and Opex for this project. Cost data was included in the various templates to enable construction cost to be used as an optimisation study objective. Tariff costs were set up to account for the operational energy costs.

Cost matters…and it was an important part of the DeeBees "realistic" approach

It was clear to the team that there were many potentially conflicting variables that would have been impossible to fully evaluate using traditional iterative methods, so optimisation was used to quickly identify a holistic design where the key design variables were optimised as a whole "interconnected ecosystem" rather than each in isolation or parametrically. Changing one key variable like building orientation or window to wall ratio for example affects the BIPV and rooftop PV contribution, shading and glazing performance requirements, daylight availability, lighting energy, heating and cooling loads, HVAC energy etc. etc. We used DesignBuilder's optimisation tool to flush out which combinations of variables provided the greatest cost-benefit.

The results of the optimisation study, which ran overnight on a network server, helped the team to very quickly identify trends in the optimal solutions. The lower net site energy optimal designs had lower glazing percentages with orientations typically near South to maximise the impact of PV, but most importantly, with due consideration to the other interconnected variables. There were clear preferences for relatively inexpensive double-glazing, LED lighting with daylight control, VRF for non-clinical areas, and varying degrees of shading on all facades except North.

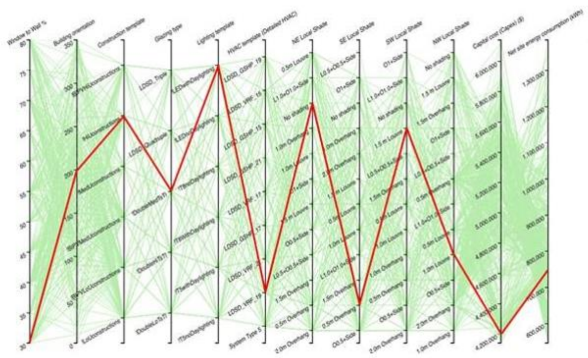


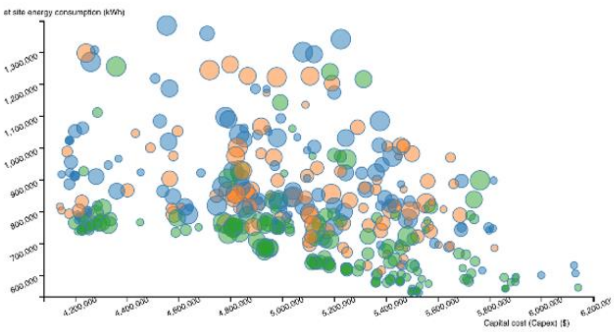
Status

Iteration	Gen...	Stat...	Window to ...	Building orien...	Construction ...	Glazing type	Lighting temp...	HVAC templa...	NE Local Sh...	SE Local Sh...	SW Local Sh...	NW Local Sh...	Capital cost (...	Net site ener...
Optimal Designs														
344	11	Opti...	30.000	150.000	!BIPVLoMass...	!DoubleMed...	!LEDwithDayl...	LDSD_VRF_...	No shading	0.5m Overhang	1.0m Overhang	Overhang + s...	5526242.754	545940.50
372	12	Opti...	30.000	200.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	No shading	0.5m Overhang	1.5m Overhang	2.0m Overhang	5497551.079	547678.86
362	12	Opti...	40.000	200.000	!BIPVLoMass...	!DoubleMed...	!LEDwithDayl...	LDSD_VRF_...	0.5m Overhang	2.0m Overhang	No shading	0.5m projecti...	5403910.663	578333.52
334	11	Opti...	40.000	200.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	0.5m Overhang	Overhang + s...	No shading	0.5m Overhang	5360431.486	579152.37
342	11	Opti...	45.000	180.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	0.5m Overhang	0.5m Overhang	0.5m Overhang	2.0m Overhang	5289969.985	614798.31
368	12	Opti...	50.000	210.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	Louvre, 0.5m...	Overhang + s...	1.0m Overhang	0.5m Overhang	5248352.432	617100.35
331	11	Opti...	50.000	220.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	Louvre, 0.5m...	0.5m projecti...	Overhang + s...	0.5m Overhang	5247029.518	621655.95
363	12	Opti...	55.000	200.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	Louvre, 0.5m...	0.5m projecti...	Louvre, 0.5m...	0.5m Overhang	5180411.891	629730.96
173	5	Opti...	55.000	220.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	Louvre, 0.5m...	0.5m projecti...	Overhang + s...	2.0m Overhang	5177035.813	637437.79
388	12	Opti...	55.000	150.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	No shading	0.5m projecti...	0.5m projecti...	Overhang + s...	5112101.414	638759.61
365	12	Opti...	70.000	190.000	!BIPVLoMass...	!DoubleHiTsTI	!LEDwithDayl...	LDSD_VRF_...	0.5m Overhang	0.5m projecti...	2.0m Overhang	0.5m Overhang	4930095.288	675705.81

The “Pareto Front” in DesignBuilder showing the range of optimal solutions

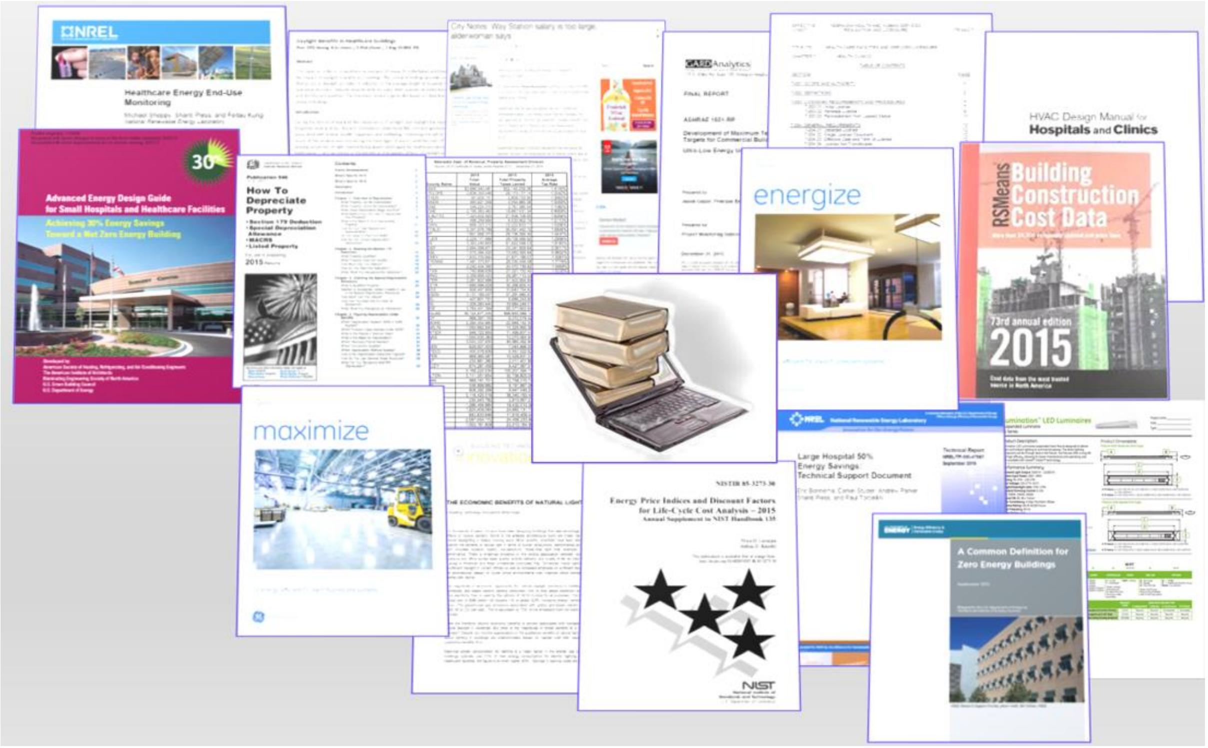
DesignBuilder’s additional bubble plot and parallel co-ordinate analysis tools were used to gain a deeper understanding of some of the variable relationships and the strengths of the different variable combinations.





Following the analysis we selected the solution with the blue dot that can be seen on the main Pareto Front graph above to the left of the vertical red line separating the BIPV and non-BIPV solutions. Comparing the two blue dots it was clear that we could save over 10% of the construction cost (approx. $600,000) with negligible impact on energy and comfort. This is a great example of how high-quality energy modelling can have such a short payback period when considering the appropriate cost savings it can identify, as reported recently by HOK’s study.

During the earlier stages Yung and Chitra had investigated relevant codes and standards that apply to healthcare buildings in Nebraska.

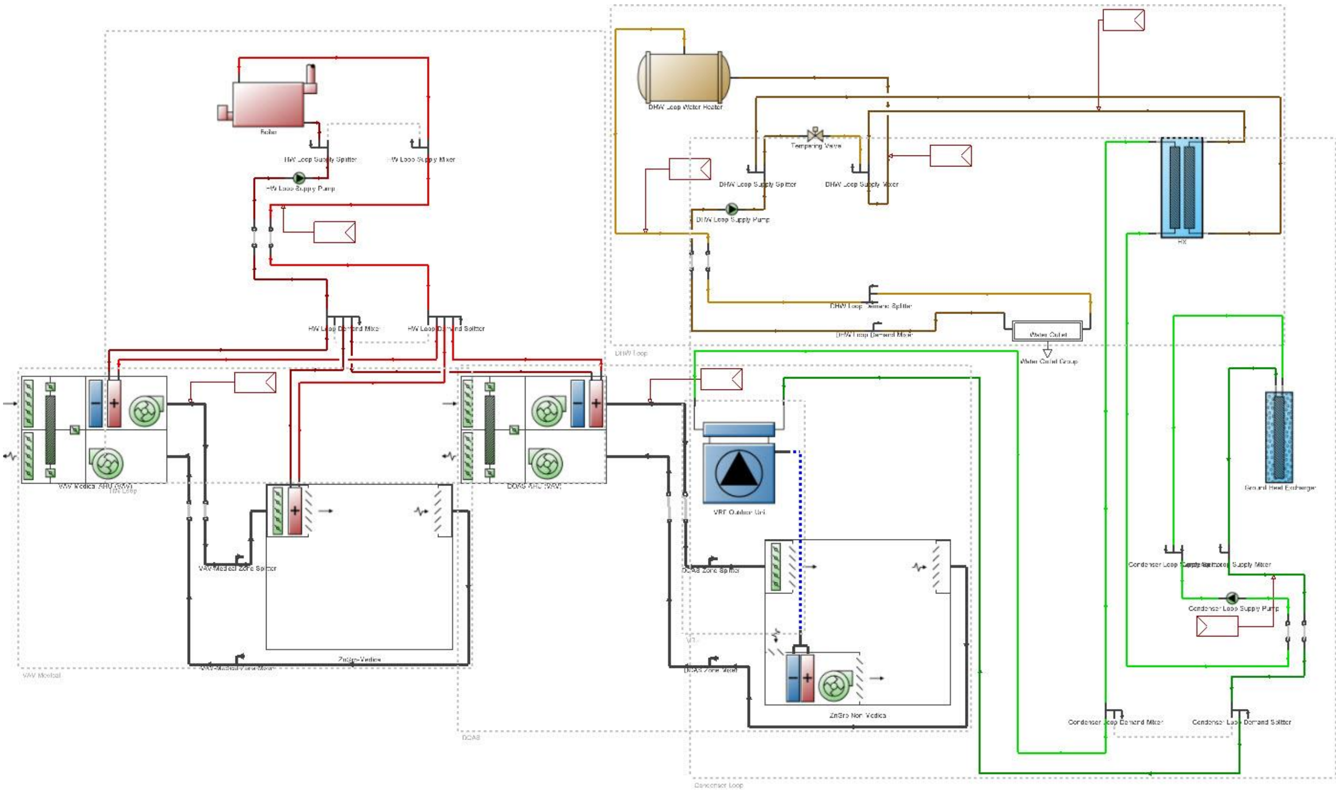


Armed with that information, Jim and Yung started work on the HVAC solution. We decided to employ a VAV system in the clinical areas on the ground floor due to the high clinical air change requirements in some zones, plus the need for a practical system that does not require normal maintenance within the “clean zone”. We selected a VRF system with DOAS to serve the two non-clinical/admin floors of the building due to its relatively low cost, high efficiency and practicality.

Heading towards detailed design

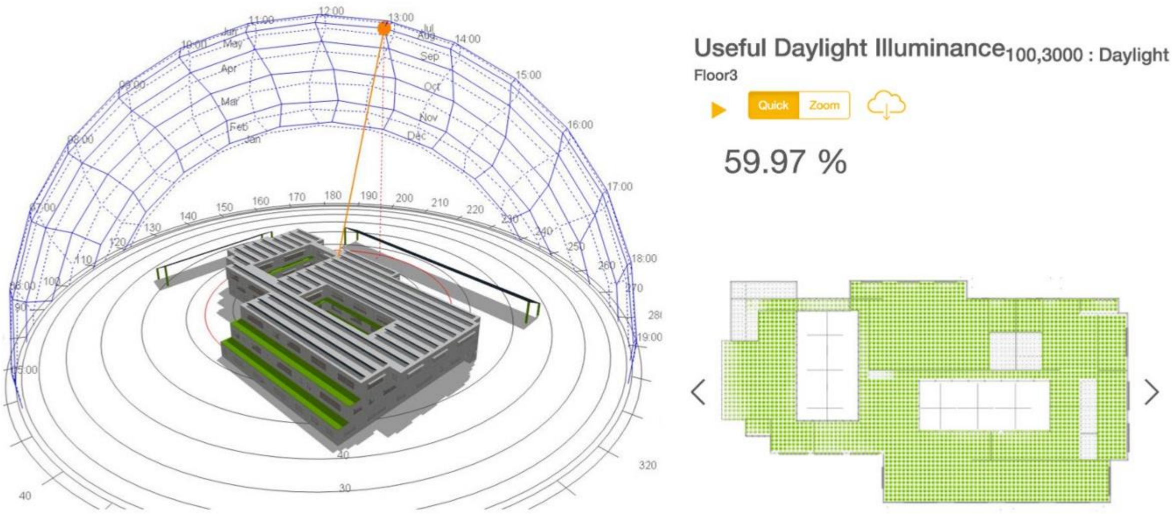
Jim and Yung continued to refine the HVAC system. Heat recovery was included in the DOAS AHU and the VRF system utilised inter-zone heat recovery to transfer energy between zones that are simultaneously in heating and cooling mode. A ground loop was added to prevent the VRF system freezing during peak winter conditions, and also to improve its year-round efficiency using ground rather than air temperatures.

Overall the building was cooling-dominated, so the HVAC design was further supplemented by a heat exchanger to enable any excess heat to be recovered from the VRF condenser and used to pre-heat the domestic/service hot water. This EnergyPlus heat exchanger component provides a huge degree of additional flexibility with the capability to connect different HVAC loops and systems in different ways.



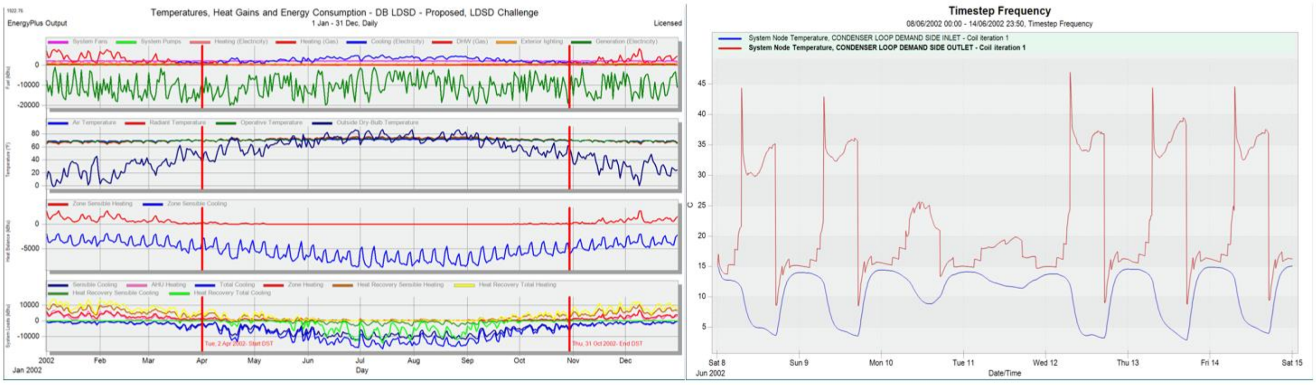
The proposed building HVAC system

We did some initial solar visualisation in DesignBuilder and daylighting analysis using our current Radiance implementation, but given daylighting was such a pivotal part of the design Sukreet wanted to use climate-based daylighting analysis to better ensure the health and wellbeing brief would be met. DesignBuilder's climate-based daylight analysis tools are still under development (due later in 2016) so Sukreet used Light Stanza to confirm the average annual illuminance, sDA and UDI.



Solar visualisation and climate-based daylighting analysis

Anybody that knows Jim probably knows how he loves to drill down into the model to undertake extensive QA/QC checks. The team started by sanity-checking basic metrics such as EnergyPlus summary reports and DesignBuilder annual simulation plots, and then reviewing design summer, winter and swing season week results in the DesignBuilder interface.

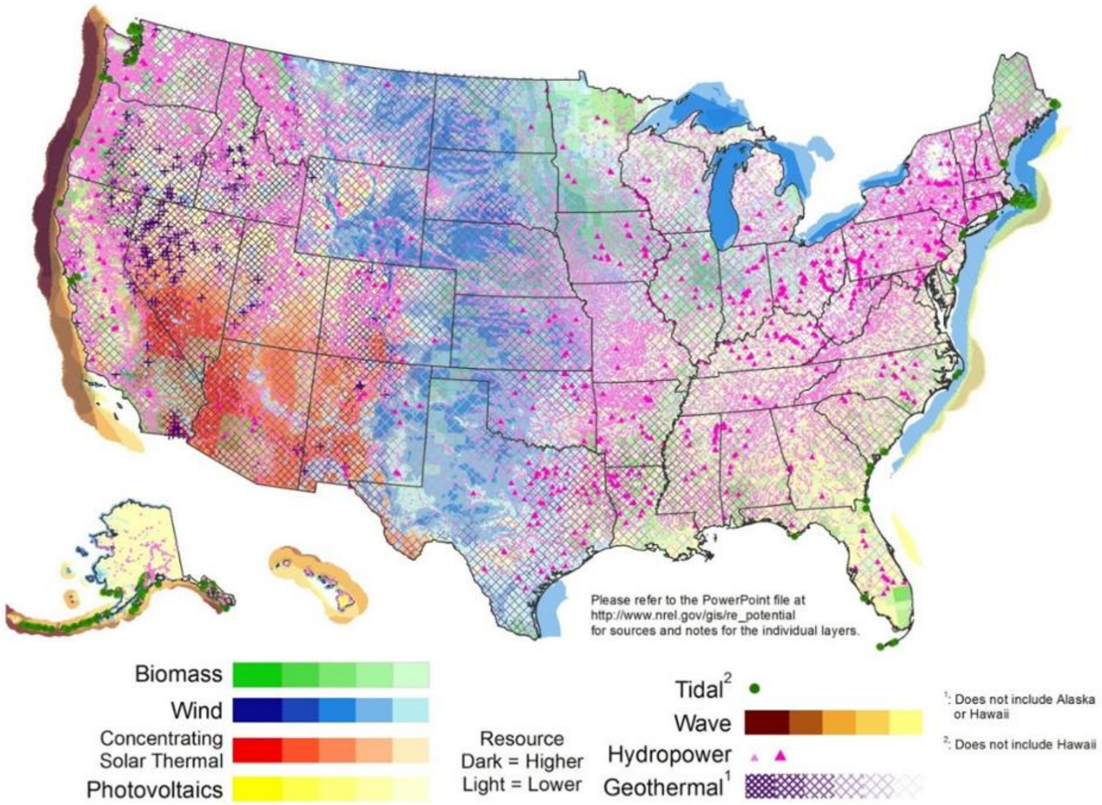


DesignBuilder and Results Viewer QA/QC checking outputs

We then used the Results Viewer to check details such as HVAC component heating and cooling coils were operating as intended and expected. Finally, Jim exported the simulation results to a spreadsheet to go the extra mile and flush out any minor residual irregularities.

Having refined the building and HVAC design, the team added the remaining 5,000 Sq Ft PV array in the car parking area and simulated the energy performance. This confirmed that our healthcare building was performing very well with an EUI before PV of 85 kBTU/ft2, and an EUI after adding the allowed 10,000 Sq Ft of PV of 68 kBTU/ft2. The proposed design improved the baseline building performance by 45% without PV, and this further improved to 56% with the allowed PV. Whilst this is great in itself, we still needed to identify and use appropriate additional renewables to reach “net-zero” and meet the competition requirements.

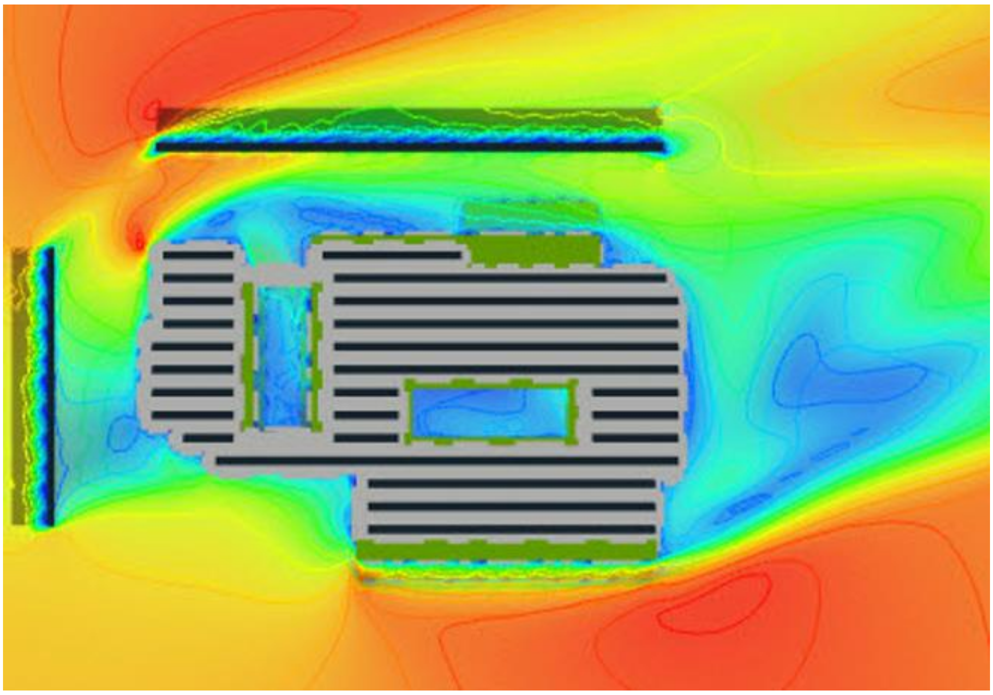
One of our [self-imposed] client Operational Performance Requirements was that our prototype building should be replicable and scalable depending on factors such as climate and site conditions. Appropriate renewables solutions will depend to some extent on the local availability of energy from biogas from landfill, biomass from forestry, watercourses suitable for hydro power etc. Another important factor is the suitability of the site itself to solutions like solar panels and wind turbines that could be adversely affected by surrounding buildings.



NREL "Renewables map" for the US

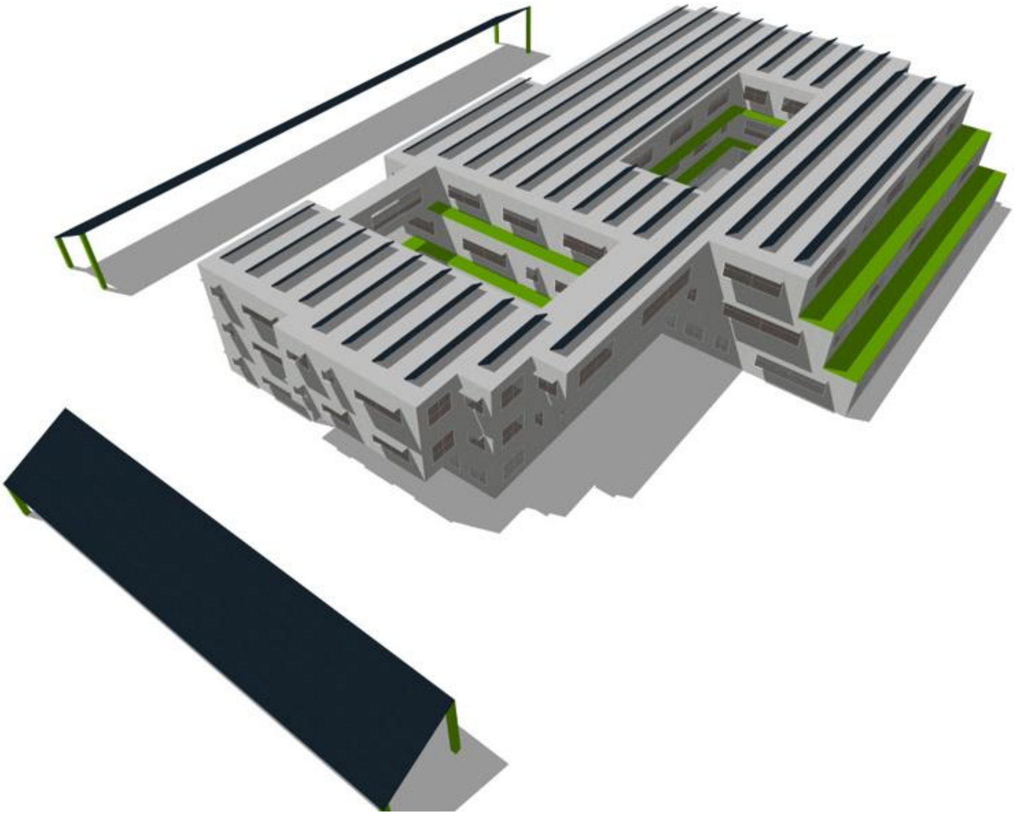
We decided ultimately that the renewables decision for this project was academic...we knew we could easily achieve net-zero by a range of different strategies depending on local conditions. In this case, given the lack of real-world constraints, we decided to select wind power, as the NREL renewables map indicates this as a potentially suitable option for Omaha (pending a site-specific wind survey of course!).

We added a 250 kW wind turbine which took us comfortably below net zero. Part of the wind turbine suitability analysis for a real-world site in DesignBuilder could include an external CFD analysis to assess how the turbine location would be affected by our own building form and local obstructions such as surrounding buildings.



External CFD analysis in DesignBuilder (run from the same proposed model)

As a final check, Weili did some uncertainty analysis on the final proposed model using tools that CMU are developing. This indicated an uncertainty of around 15% which the team felt was appropriate for this relatively early-stage design.



The DeeBees final proposed building model visualised in DesignBuilder

Presentation

Now the team could really start to concentrate on ASHRAE's submission requirements and the all-important presentation. Aaron and Jim led the presentation which was informative whilst being energetic and fun; it was extremely well received by their peers in the voting audience.

Jim and Aaron "wow" the SimBuild audience with the DeeBees presentation

Summary

The take-home points from the DeeBees presentation summary were:

- The proposed design is creative and unique in that it primarily focuses on occupant health and wellbeing, was created from analyses using multiple simulation engines within DesignBuilder, and combines ground-source VRF technology with various heat recovery mechanisms.
- The overall workflow process was streamlined and efficient thanks to templates and other DesignBuilder features. Modelling issues were quickly discovered and remedied thanks to an extensive quality control process.
- The proposed design is cost-effective and practical, using real world technology available today. Plus, it is well suited to adapt as technology and economics evolve.
- The team comfortably exceeded their stated OPR minimum requirements in terms of performance. Although not counted in the official figures, the team estimated an additional $1.4M indirect benefit associated with the "health and wellbeing" strategy.
- Following the presentation there was a panel Q&A session where team captains were put in the firing line to face audience questions. This stimulated some lively debate about the

different approaches and results between submissions. Jim responded to the questions supremely well in his usual calm, reflective and thoughtful manner!

Award

After the Q&A came the audience vote...we were all delighted that the DeeBees were presented with the "Best Energy Performance" award.


The Award for
Best Energy Performance
for the ASHRAE LowDown Showdown Modeling Challenge
is awarded to:
The DeeBees
for excellent execution on Thursday, August 11, 2016
M. Dennis Knight
M. Dennis Knight
ASHRAE and IPBPSA-USA 2016
SimBuild
Conference Chair
ASHRAE®

The fruit of the DeeBees labour!

The competition was challenging but fun and professionally rewarding for all involved. The teams all did a great job and, considering they were all volunteers, the standard of the entries was impressively high. The DeeBees all got a great deal of satisfaction from their experience on the team, with the recognition from the voting ASHRAE audience at the end being the icing on the cake.

Webinar - Learn More

To fill in the gaps and provide more details on how DesignBuilder was used by the DeeBees during the competition Dave and Jim presented a webinar on 6th October 2016. You can watch the recording by clicking on the link below.

[Watch the Recording of the Webinar explaining the prize-winning design process]