Front perspective of the design building

High Performance Sustainable Building Design Strategy: Form Follows Performance

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Abstract

Climate change is seen as the greatest challenge to mankind. The first impact of such a change will be reflected in the cities and buildings we live in. So, we have to start thinking and prepare ourselves to adapt and become resilient to this change. Our aim is to design a high performance building that performs not only today, but also thirty years hence when a two degree Celsius rise in air temperature is predicted. We employ the use of an urban farm as the outer envelope and establish a meticulous balance between architectural quality and performance matrix. A novel concept of form follows performance propels the design process. Natural resources of wind and sunlight are utilized to the apex validated by simulations, thus aiming to achieve a benchmark energy consumption of 150 kWh/m^2.yr in Singapore.

Design Philosophy

Today, designers are interested not only in the form; a cultural expression of the artist-creator, but also in an articulated understanding of the built environment propelled by an enhancement of technological tools and information access opportunities. How can we reduce the impact of 'human activities' on earth and provide comfortable and healthier buildings and cities at the same time? A possible answer lies in a different design

About the Authors

Rupesh Iyengar is a university topper in mechanical engineering from BMSCE, Bangalore and an M.Sc. gold medallist in Sustainability from the National University of Singapore. He is the only Indian in the world panel of researchers at ETH, Zurich and The Future Cities Laboratory where he pursued his Doctorate in Sustainability and Zero Emission Design. He has published over 10 research papers. He was session chair on Sustainability and Green Buildings during the 10th Healthy Buildings Conference in Brisbane. He is a board member and secretary of ASHRAE Singapore Chapter, and heads YEA for ASHRAE in South East Asia. He was ASHRAE Global New Face in 2012, 2013, 2014 and 2015. His company Index Workshop Inc., with branches in Singapore and Italy, is involved in sustainable design and zero energy building projects.

Ermanno Cirillo is an Italian designer who has studied architectural engineering in Milan and Madrid. He has been working on projects in Milan, New York and Singapore. He is a registered professional in Italy.

Satish Iyengar completed his engineering in M&E in 1978 and masters in business management from Mumbai. He was a management trainee in Crompton Greaves before he joined Voltas, where he worked in Mumbai and Bangalore. He started Services Consultants in 1988 specializing in MEP, IBMS and sustainability services consultancy, which he still heads. He is also associated with Index Workshop Inc. He is a founding member and Chapter President Emeritus of ISHRAE Bangalore Chapter, and was thrice Co-chairman of ACREX. He is a past National President of ISHRAE. He is a member of ASHRAE, Electrical Consultants Association and Indian Plumbing Association.

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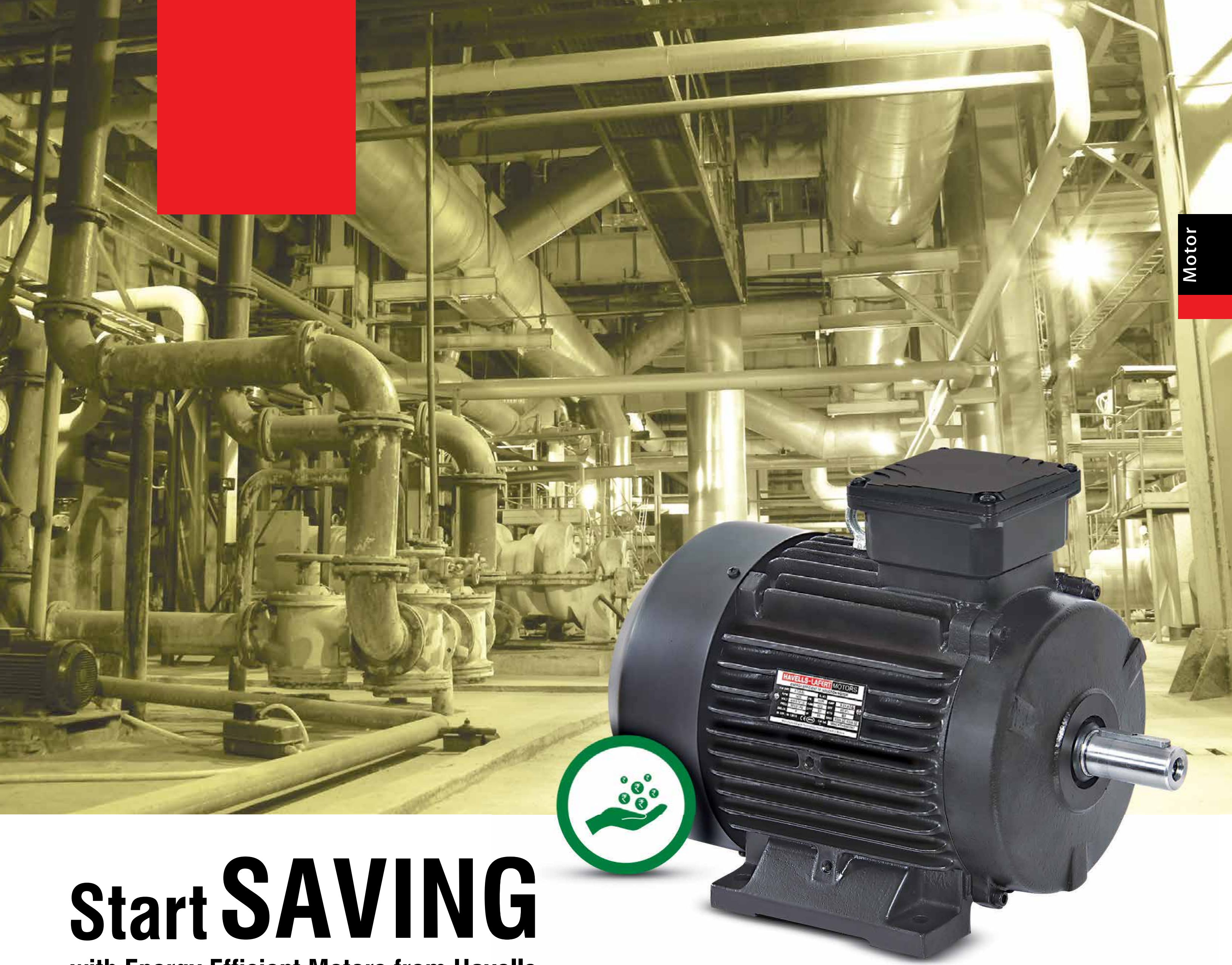

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Roof Angle

Selecting roof slopes for maximizing wind velocities in the central region

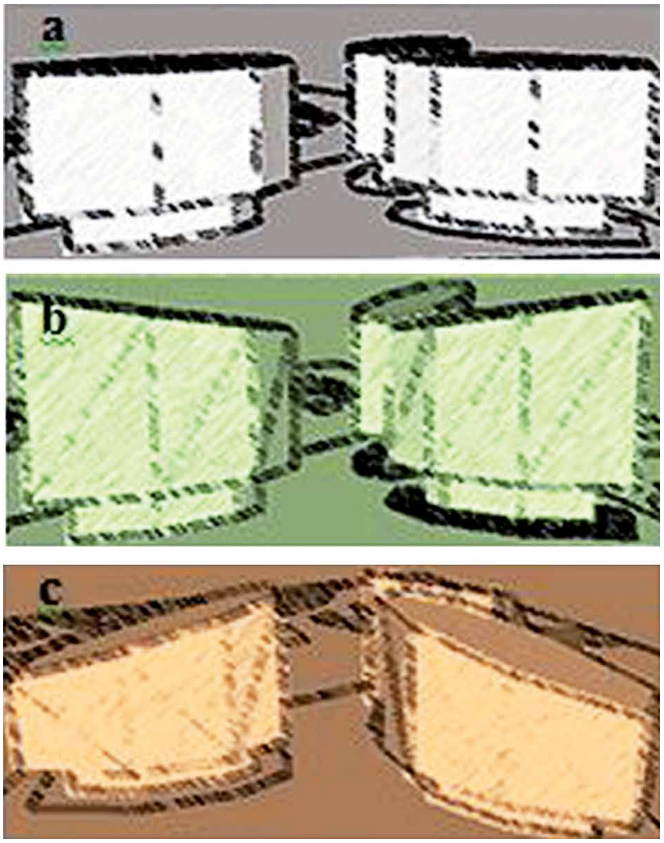

Figure 5: Roof slopes, a) 0°, b) 6° and 12° (downward), c) -6° and -12° (upward)

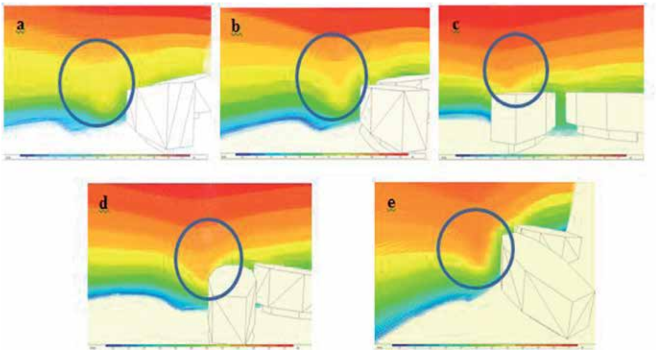

Figure 6: Wind velocity in central region, a) 12°, b) 6°, c) 0°, d) -6°, e) -12°

Upward roof slopes increase wind velocities in the central region as validated by the increasing intensity of the funnel in the CFD simulations. A roof slope of -12° (2 m/s wind velocity) is selected, which naturally ventilates the central collaborative region.

Courtyard Angle

Selecting courtyard slopes to maximize daylight

An ethylene tetrafluoroethylene (ETFE) roof is used to minimize the solar gain increase caused by sloping courtyard façades to increase daylight. Energy consumption, solar gain and daylight are

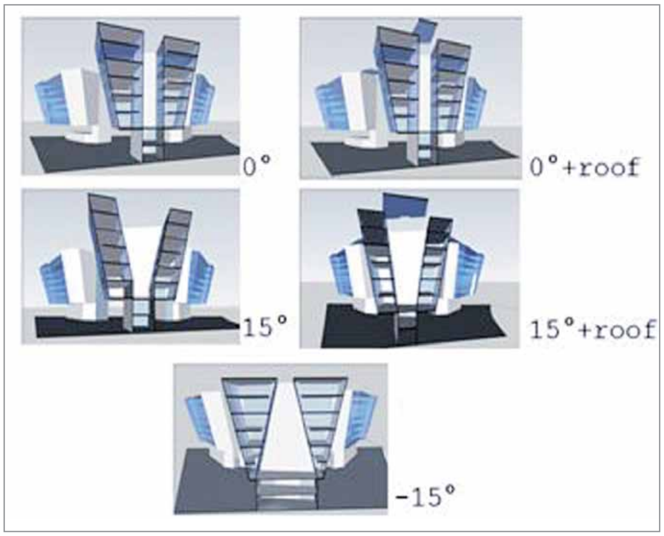

Figure 7: Courtyard slopes

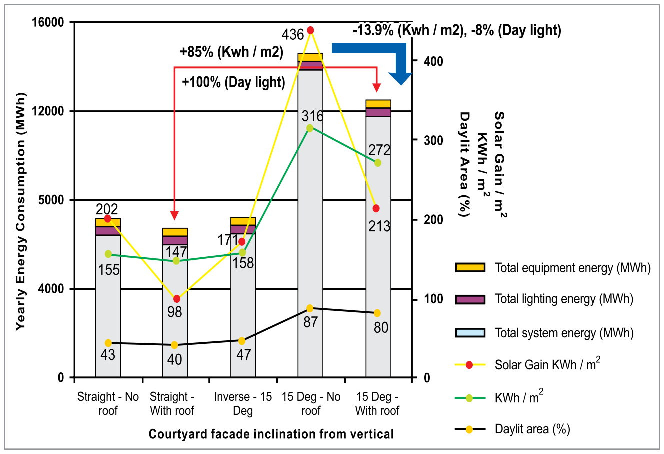

Figure 8: Energy v/s daylight comparison across courtyard slopes

relatively studied. 300 lux is set as the minimum threshold level for daylight. Collaborative spaces dispersed in the atrium in the form of 'projecting pods' are innovatively ventilated by routing cool and treated exhaust air from air conditioned offices.

Vertical Farm

Vary covering ratios to minimise solar gain and balance daylight

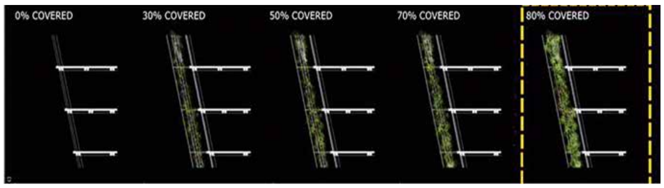

Figure 9: Covering ratios variation schematic

The building integrated vertical farm adopts hydroponic plant systems where tomatoes, cauliflowers, cucumber, lettuce, etc. are grown. The fresh produce is used for in-house consumption. The density of hydroponic plantation is varied on the façade to achieve customised daylight. The efficacy of the green layer has been evaluated on two criteria: surface temperature of the glazing and total energy consumption.

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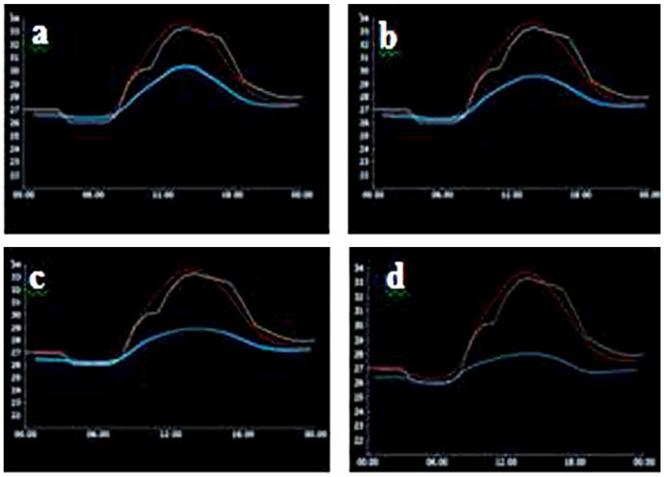

Figure 10: Surface temperature profiles, a) 30% covering, b) 50% covering, c) 70% covering, d) 80% covering

The white line represents the outdoor air temperature. The red line is the surface temperature without the vertical farm. The blue line represents the surface temperature with vertical farm.

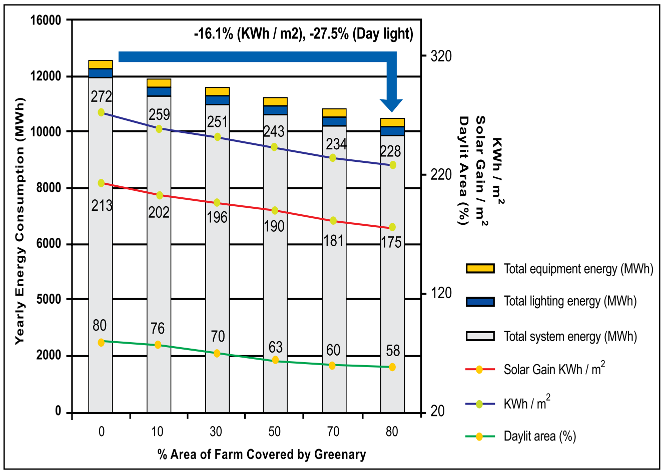

Figure 11: Energy v/s daylight variation across covering ratios of vertical farm

For an 80% covering ratio, 58% of the day-lit area is above 300 lux. This will help, in any case, the reduction of lighting energy, which is not taken into account, giving a worst-case scenario for the evaluation. The total energy consumption at the end of passive strategy optimization is 228 kWh/m²·yr.

Active System Optimization

To increase the efficiency of the system

A water-cooled screw compressor chiller with COP 6 is used in the intermediate stage incorporating heat recovery devices, 95% efficient motors and VSD pumps. The final optimized case has magnetic bearing compressors with COP 8 (Singapore conditions).

Optimizing the active system, has increased efficiency and has finally achieved an energy consumption of 138 kWh/m²·yr within the benchmark value of 150 kWh/m²·yr. The same iterative process was repeated for a 2°C rise in air temperature in the future scenario.

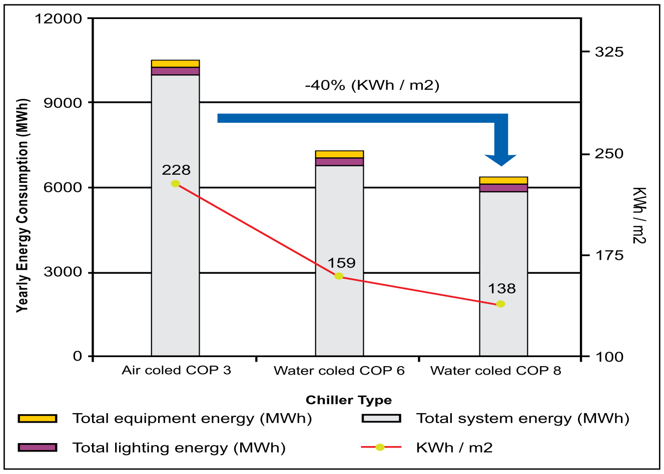

Figure 12: Energy variation across active system optimization stages

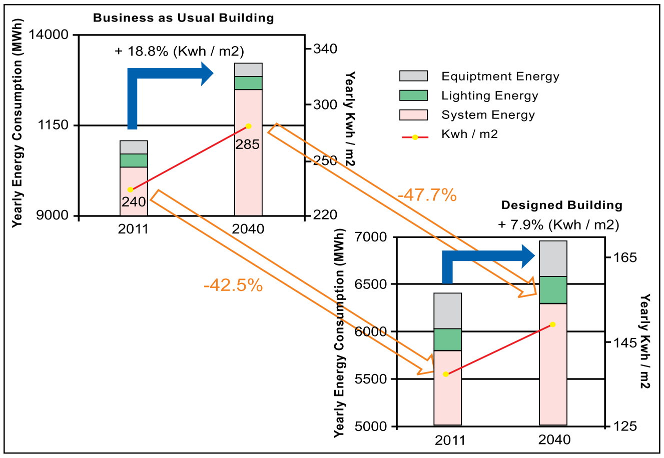

Figure 13: Energy comparison between Business As Usual (BAU) and Designed Building

Conclusion

- The design building will consume 42.5% lesser energy than a comparable BAU building in Singapore.
- Energy consumption of a BAU building will raise 18.8% with an air temperature rise of 2°C, whereas the design building will only have a 7.9% rise in energy consumption, owing to the urban farm's potential to keep the solar insolation and façade heat gain constant.
- Thirty years hence the design building will consume 149 kWh/m²·yr of energy, which is still under the benchmark value of 150 kWh/m²·yr. It will consume 47.7% lesser energy compared to a BAU building in Singapore, at that time.
- The vertical farm strategy plays an active role in reducing energy consumptions and ensuring resilience to climate change.

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Notes

- This paper was presented at the 10th Healthy Building Conference 2012 in Brisbane, Australia and 18th International Sustainable Development & Research Conference 2012 in Hull, UK with global accolades. References can be made to the conference proceedings.
- This project also won the Green Design Award of Merit at the International Green Building Congress – Singapore Green Building Congress 2011.
- Special thanks to Vignesh Kaushik, Nittin Vignesh, Venkateshan Jayaraman and Dr. Chandra Sekhar for their help and contribution.