NANYANG
TECHNOLOGICAL
UNIVERSITY

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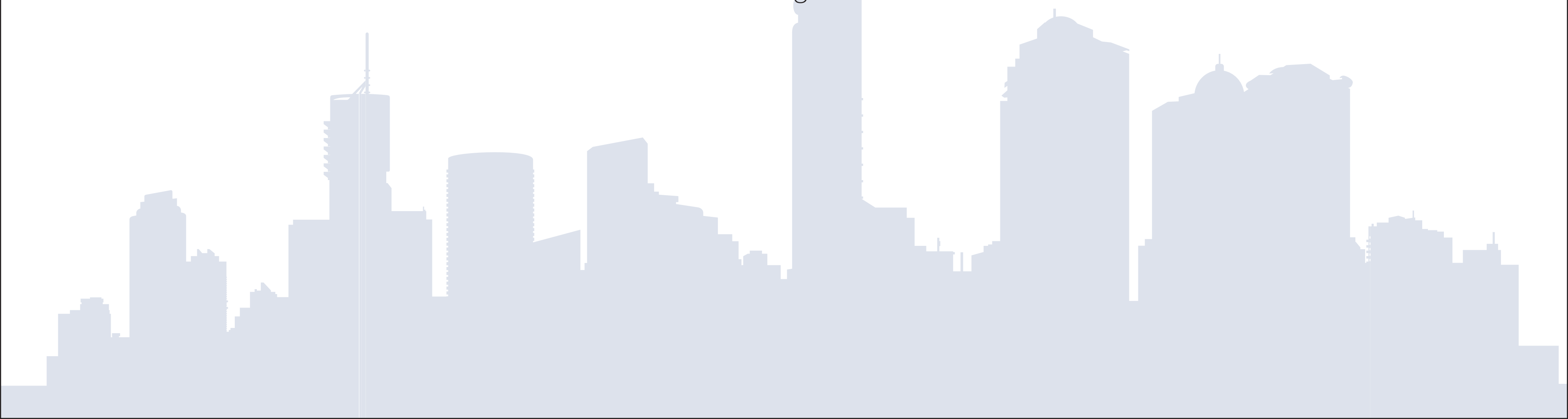
Iconic

Cutting Edge

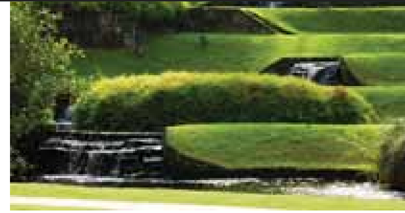
Highly Energy Efficient

Buildings for the Future

Contents



Introduction



NTU will invest nearly $700 million in new building projects to be completed over the next three to four years. By constructing iconic, cutting-edge and energy-efficient buildings on our campus, we signal our aspiration to become one of the world's top engineering and science centres and a leader in areas such as clean technology and environmental sustainability.

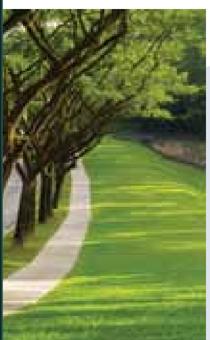
NTU's Sustainable Earth Peak provides an opportunity for the university to do more with sustainability, both in research and in practice.

At the Sustainable Earth Peak Retreat held on 15-16 September 2011, the NTU community began developing an action plan to determine key priorities in sustainability research and practice. The faculty and university community agreed that NTU should undertake sustainable building projects with a specific emphasis on energy efficiency. To advance and further explore this mandate, the NTU Sustainable Earth Office's (SEO) Energy Efficient Building Workshop on 5 October 2011 was organised to gather resources and discuss key challenges to assist with building energy-efficient structures in tropical climates. Over the course of this eventful one day workshop, it became apparent that NTU and its local partners had all the talent, expertise, and ideas necessary to build our own outstanding energy-efficient buildings.

Within the next three to four years, NTU is committed to building several iconic, energy-efficient structures that will embody the talent and creativity of this world-class university.

By way of preview, and after much discussion on benchmarks and possibilities, it was decided that NTU should strive to achieve a final energy consumption in buildings of 50 $kWh/m^2/yr$.

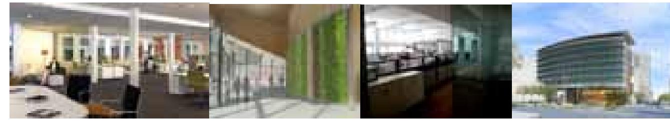
To be specific, this 50 $kWh/m^2/yr$ target applies to final energy consumption, but does not apply to renewables (for which building projects will receive offsets), and does not include servers (which is a necessary exclusion, since not all buildings house these internally). In addition, this excludes specific laboratory infrastructures, like energy-consuming equipment. Finally, this target will be achieved as an average across all new buildings on campus with their different energy needs (laboratories, offices, dormitories, and the like). In short, this is a very ambitious goal, and to demonstrate exactly how ambitious, we commissioned studies on state-of-the-art energy-efficient buildings throughout the world and in Singapore.

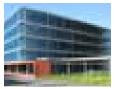
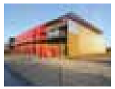
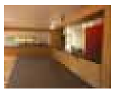
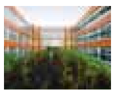
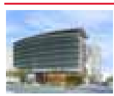
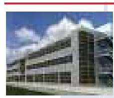
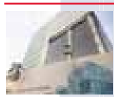
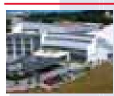
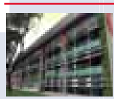


Some of the world's best projects from these reports are highlighted below, and are translated into our benchmarking metric of 50 $kWh/m^2/yr$ to simplify comparison. The big challenge in a tropical climate is cooling and desiccation, and our architects and designers, with the support of NTU's own engineering expertise, will have to innovate new solutions to meet our targets. In fact, NTU's buildings will be competitive with many of the world's top projects, and will be among the very best energy-efficient buildings ever constructed in a tropical climate.

This brochure was created to give the NTU community, our alumni, our Singaporean project partners and friends, and interested parties the world over, an introduction into how much we are going to achieve here over the next several years, and how we are going to do it.

Summary of State-of-the-Art Energy-Efficient Buildings around the World



	Building	Climate zone	Final Energy [kWh/(m^2/yr)]	Primary Energy [kWh/(m^2/yr)]
	Eawag, Zurich	Warm temperate	14,0	36,3
	"NuOffice", Munich	Warm temperate	58,9	129,2
	CPW, Orbe	Warm temperate	73,2	191,3
	"Biohaus", Bemidji	Cold	31,9	83,0
	CIRS, Vancouver	Warm temperate	72,9	76,0
	OSC, Portland	Warm temperate	56,8	94,3
	Siemens Tenjo, Bogota	Equatorial	15,9	31,8
	SCS, Shanghai	Warm temperate	75,6	173,3
	PTM, Kuala Lumpur	Equatorial	35,0	58,1
	BCA, Singapore	Equatorial	59,3	98,5

Note 1: As part of NTU's examination of other energy efficient building projects around the world, the SEO recently commissioned a study by Intep, a leading, international strategic consultant group with construction work throughout Germany, Switzerland, and the United States, including the management of complex building projects with a variety of sustainability objectives. This table is a summary of work from that full report (see http://sep.ntu.edu.sg).

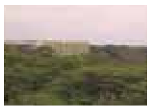
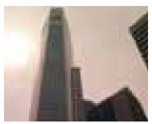
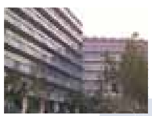
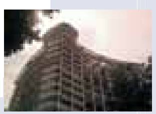
Note 2: The buildings in this table have an energy consumption that is 5 to 10 times lower than conventional buildings. Furthermore, what all these projects have in common is that a clear goal for energy-efficient design was adopted from the beginning.

Note 3: Buildings are one of the heaviest consumers of energy and use about 40% of the raw materials globally. In the U.S., buildings account for 38% of all CO_2 emissions (Source: U.S. Energy Information Administration 2008 Assumptions to the Annual Energy Outlook). Standards like the Living Building Challenge in the U.S., the German Passive-House-Standard or the Swiss Standard MINERGIE-P support the achievement of energy efficient buildings. As such, energy efficient buildings have a large positive impact on the environment.

Note 4: Final Energy is the energy available in the building. This includes the delivered energy and the energy used at the site and recovered. The final energy demand is the total measured consumption in the building for heating, cooling and electricity.

Note 5: Primary Energy is the energy form found in nature that has not been subjected to any conversion or transformation process (oil, gas, uranium, coal, wood, solar radiation etc). It is energy contained in raw fuels, and other forms of energy received as input to a system. Primary energy can be non-renewable or renewable.

Summary of State-of-the-Art Energy-Efficient Buildings in Singapore

	Building	EEI $kWh/m^2/yr$	Estimated Energy Saving kWh/yr	Estimated Water Saving m^3/yr	ETTV W/m^2
	BCA Zero Energy Building	59.3	388,720 *Actual Saving* *207,000*	3,620	43.79
	School of Art, Design & Media, NTU	130	*Actual Saving* *120,000*	1,170	NA.
	Clean Tech Park, JTC	100	9,345,210	11,217	30.81
	Ocean Financial Centre	174	9,080,000	42,000	42.76
	Tampines Grande	149.7	2,700,601	71,300	39.5
	Fuji Xerox Towers	138.7	2,998,596	65,106	NA.
	National Library Building	145-151	821,000	56,240	NA.

Note 1: This table of state of the art energy efficient and sustainable buildings around Singapore is a summary compiled by the Institute of Environmental Science and Engineering Pte Ltd (iESE), a group created to focus on environmental technology at NTU. As demonstrated, Singapore has already done some good projects, but we believe is now ready for the next quantum leap forward. And NTU is well-positioned through its campus building programme and by virtue of its expanding expertise to play an important role for the nation.

Note 2: EEI: Energy Efficiency Index (kWh/m^2/yr). EEI is a building performance indicator to measure the building's unit area energy consumption for future monitoring and improvements. Besides its use as a performance indicator, 1 point is scored for the practice of using EEI in Green Mark calculations. Calculation: EEI = [(TBEC - DCEC) / (GFA – DCA)] x (NF/OH), where: (a) TBEC : Total building energy consumption (kWh/year); (b) DCEC : Data centre energy consumption (kWh/year); (c) GFA : Gross floor area (exclude car park area) (m^2); (d) DCA : Data centre area (m^2); (e) NF : Normalising factor based on a typical weekly operating hours that is 55 hrs/week; (f) OH : Weighted weekly operating hours (hrs/week). And Note: (1) EEI is based on 100% occupancy rate for consistency; (2) All major energy consumption equipment are to be included in the estimation of total building energy consumption; and (3) For industrial buildings, process load should be excluded. (Reference: BCA Green Mark for Non-Residential Building Version NRB/4.0).

Note 3: ETTV: Envelope Thermal Transfer Value (W/m^2): measures the overall thermal performance of building envelope with an aim to minimise heat gain thereby reducing the overall cooling load requirement. It is applicable for air-conditioned non-residential buildings and with aggregate areas > 500m^2. Responsibility for measurement lies with the Qualified Person, QP(BP). Calculation is based on a formula set out in the "Code on Envelope Thermal Performance for Buildings" issued by the Commissioner of Building Control, Singapore. Maximum permissible ETTV (Baseline) must not exceed 50W/m^2. Prerequisite Requirement for Green Mark Platinum – ETTV of <=40 W/m^2. In Green Mark calculation, 1.2 points are deducted for every reduction of 1W/m^2 in ETTV from the baseline.

Outline of NTU's Strategic Building Plan and Work in Progress

As highlighted in the introduction, the decision and process to build energy-efficient structures at NTU began at the Sustainable Earth Peak Retreat and Energy Efficient Building Workshop by building broad consensus, creating an awareness of community ownership, identifying the primary stakeholders, and organising some of the university's key resources.

From these beginnings, the SEO helped organise a group of dedicated and motivated project supporters from ERI@N (Energy Research Institute @ NTU), NEWRI (Nanyang Environment & Water Research Institute), ODFM (NTU's Office of Development & Facilities Management), SCE (School of Computer Engineering), and iESE (Institute of Environmental Science and Engineering). The first meeting of a provisional Building Working Group (BWG) occurred on 6 October 2011 in order to discuss the best ways forward for achieving NTU's ambitious project goals.

This provisional BWG subsequently produced a comprehensive proposal that was submitted to the Office of the President in November 2011 to put in place the administrative structures and resources necessary to effectively direct and oversee the process of building outstanding energy-efficient buildings on NTU's campus.

As of December 2011, many of these proposals have been or are in the process of being implemented, including:

- Establishing a fully authorised Building Working Group inclusive of NTU's best talent suited to the executive functions of the project's building-related focus, and assembled to ensure early and active consideration of good design options, alternatives, project-specific benchmarks, targets, and technologies.

- Installation of a Provost-level Campus Building Director to perform vital oversight functions over the BWG and all of the campus building projects.

- Modifying the University's current review and scoring process for the selection of architects, builders, and general contractors for campus building projects in order to strike a balance between hiring the best architects and building contractors to innovate workable energy-efficient solutions while simultaneously guiding the selection process by providing clear expectations and targets up front.

Another idea generating some excitement around NTU is to retain an architect of international renown for one or more of these upcoming building projects. This would be a great marketing and profile-raising opportunity for the university. Not only would NTU be displaying its showcase energy-efficient buildings, but these same structures would also become iconic and architecturally significant regionally and throughout the world.

In conclusion, NTU's plan to build cutting-edge and iconic energy-efficient buildings on its campus is an ambitious enterprise, one that would have far-reaching consequences. These are goals, however, that we are confident of achieving: NTU has the right executive administration, world-class engineering and management talent, the support and enthusiasm of the entire university community, and a solid strategic plan.

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