The Role of International Partnerships in Delivering Low-Energy Building Design: A Case Study of the Singapore Scientific Planning Process

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THE ROLE OF INTERNATIONAL PARTNERSHIPS IN DELIVERING LOW-ENERGY BUILDING DESIGN: A CASE STUDY

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ABSTRACT

This paper explores the role of international partnerships to facilitate low-energy building design, construction, and operations. We briefly discuss multiple collaboration models and the levels of impact they support. We present a case study of one collaborative partnership model, the Scientific Planning Support (SPS) team. Staff from the Lawrence Berkeley National Laboratory, the Austrian Institute of Technology, and Nanyang Technological University formed the SPS team to provide design assistance and process support during the design phase of a low-energy building project. Specifically, the SPS team worked on the Clean Tech Two project, a tenanted laboratory and office building that seeks Green Mark Platinum, the highest green building certification in Singapore. The SPS team hosted design charrettes, helped to develop design alternatives, and provided suggestions on the design process in support of this aggressive energy target. This paper describes these efforts and discusses how teams like the SPS team and other

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partnership schemes can be leveraged to achieve high performance, low-energy buildings at an international scale.

KEYWORDS
International partnerships, Sustainability, High-Performance Buildings, Design process

1 INTRODUCTION

Design assistance partnerships often contribute to capacity building and “out of the box” thinking that in turn facilitates energy savings. Design assistance partnerships also contribute to knowledge transfer and challenging the status quo for design and operation of commercial buildings (U.S. DOE 2011). In particular, design assistance teams may be most effective on high-energy-intensity buildings, where operational requirements may eliminate some ‘typical’ low-energy strategies and technologies (e.g., higher temperature setpoints, common in low-energy office buildings, may not be possible in laboratory settings). Design assistance teams can review literature and provide institutional knowledge to broaden the range of low-energy solutions considered for a given project, increasing the likelihood that energy savings will be realized.

This paper briefly describes several international collaboration models that support low-energy, high performance buildings. In particular, these collaborations may be most effective in Brazil, Russia, India, and China, where economies and energy demand continue to rise (U.S. EIA 2011). In fact, the U.S. Energy Information Administration (U.S. EIA) forecasts international energy demand will increase 53% from 2008 to 2035, with most of the growth attributable to non-Organization for Economic Cooperation and Development (non-OECD) countries (2011). Non-OECD countries, India and China in particular, represent a unique opportunity because much of the infrastructure is new. Thus, builders can design and construct energy-efficient commercial and residential buildings from the outset, rather than retroactively creating policies and technologies to manage exorbitant consumption (e.g., (Banerjee and Solomon 2003; Geller et al. 2006).

Glasbergen and Groenenberg (2001) further explain international collaboration is often required to solve international problems, like climate change. Tae and Shin (2009) reaffirm this view and enumerate other benefits of international partnerships and collaborations, particularly for low-energy buildings, including opportunities to adapt international policy and standards to a local context and educational opportunities. To the former point, Thilakaratne and Lew (2011) cite the prevalence of LEED in Asia, in India and China in particular, and suggest that Asian countries may want to work with U.S. collaborators to develop their own green building rating systems that address the unique climate needs of individual Asian countries. Finally, to the latter point, Kua and Lee (2002) highlight educational benefits of international partnerships and collaborations centered on low-energy buildings, especially when collaborations include exchange programs and face-to-face meetings.

We present one international partnership model, known as a Scientific Planning Support (SPS) team, in detail. We discuss the SPS experience on a case study project in Singapore. Specifically, we discuss the composition and role of the SPS team and how their outputs contributed to the design of a low-energy laboratory building. We further discuss the benefits of SPS teams and suggest where these may be strategically deployed.

2 INTERNATIONAL PARTNERSHIP AND COLLABORATION MODELS

Collaboration models for buildings research and development (R&D) span a spectrum from potential public-private/ domestic and international partnerships. Figure 1 shows different levels of collaboration models, ranging from multi-lateral programs, which are broadest in terms of impact, to institutional collaborations, which are narrowest in terms of impact, but may be the deepest in terms of savings achieved. The benefits from these collaboration models are many. Firstly, an international team can offer unbiased, scientific, innovative, and effective solutions to drive energy efficiency with an unprecedented speed and scale. Secondly, collaboration models that draw upon global expertise support knowledge transfer through lessons learned and insights, which in turn facilitate “leaps and breaks” in building energy efficiency for the host country. The latter may be more effective as game-changing advances in the field of building energy efficiency compared to incremental improvements through only in-country approaches. Thirdly, complementarity in learning through bi-lateral or multi-lateral R&D can create a powerful and synergistic approach that supports a mutual evolution of building energy efficiency in the collaborating countries.

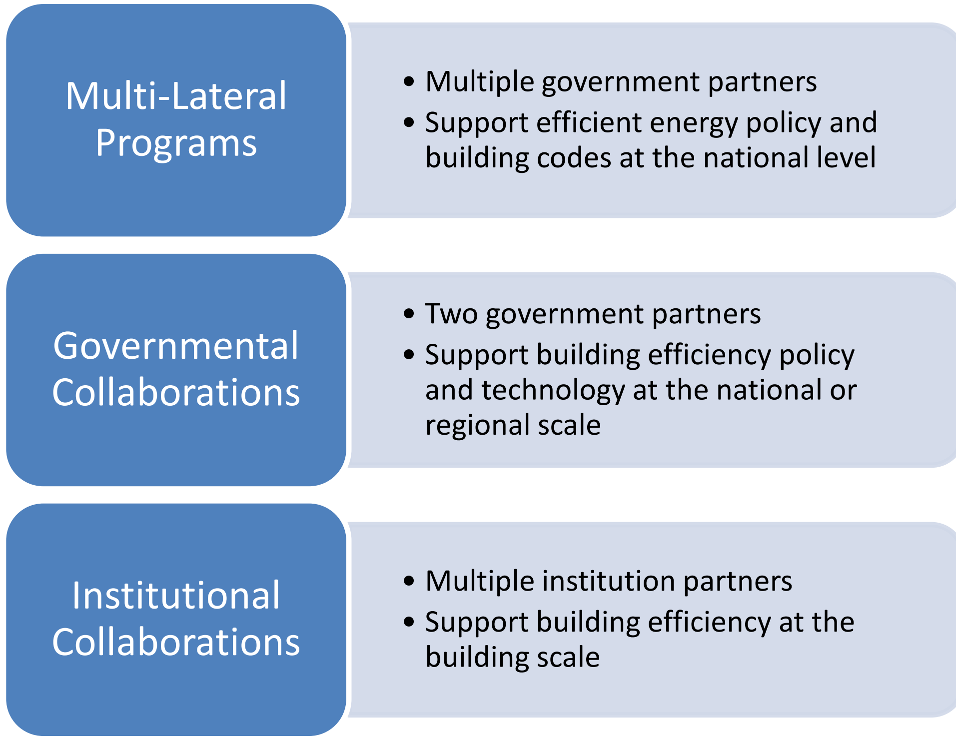

Figure 1. Three Levels of Building Energy Efficiency Collaboration Models

Multi-lateral programs in energy-efficiency offer an effective means for regional or global–scale collaboration. For instance, the Lawrence Berkeley National Laboratory (LBNL) participates in the Climateworks Global Buildings Performance Network, an organizational partnership between the U.S., E.U., China, and India for mutually beneficial work in building energy codes and labels. Similarly, through the Clean Energy Ministerial, LBNL is advancing technical expertise in energy efficient appliances to spur the transition to clean energy in 24 countries.

Governments may also form partnerships that may have wide-ranging policy implications within the partner countries. For instance, LBNL is leading two bilateral programs—initiated through Memoranda of Understanding at the national government level—where researchers and design experts from both countries collaborate to push the envelope for building energy-efficiency. The first, the U.S.-China Clean Energy Research Center for Building Energy Efficiency (CERC-BEE) seeks to build a foundation of knowledge, technologies, tools, human capabilities, and relationships that position the United States and China for a future with very low energy buildings resulting in very low CO_2 emissions. This collaboration has strengthened the capabilities of Chinese institutions to promote energy efficiency. Moreover, as this collaboration proves fruitful at the building level, both parties are shifting their focus to scaling up energy efficiency to the city level through the China Low-Carbon Cities and Eco-cities programs.

The U.S.-India Joint Center for Buildings Energy Research and Development (CBERD) program represents a second example of government-level collaboration. This project, recently awarded to LBNL under the auspices of the U.S.-India Partnership to Advance Clean Energy (PACE), seeks to draw upon the complementarity of R&D partners' experience and knowledge to deliver strategies for building lifecycle performance assurance while emphasizing solutions that leapfrog transitional technologies. In India, these solutions would be for new construction since two-thirds of the commercial building stock is still to be built, while in U.S. these would be pertinent the commercial building retrofit market.

Finally, the most granular of the collaboration models, institutional partnerships, can take multiple forms, ranging from formal relationships with memoranda of understanding, to joint research centers, to service-learning opportunities for students. Each of these offer unique opportunities for efficiency gains, education, and impact. For instance, formal relationships typically center around a specific project and achieve deep savings on that project. Joint research centers may target a city-level impact and work across projects to deploy specific strategies or technologies and prove their effectiveness. Finally, service-learning opportunities typically focus on education as the first priority, and may seek efficiency as a second priority (Pearce and Russill 2005).

The partnership we describe for the case study project presented in this paper represents a formal partnership at an institutional level, with deep, long-term collaborations on specific projects (e.g., the CleanTech Two, CTT, project described later in this paper). Such partnerships help in developing trust and solidifying relationship building at the institutional and personal levels. These can lead to results larger than the project itself, such as interest in developing best practices for highly energy-efficient, high-performance buildings. For instance, the Smart Lab concept developed for the CTT building (discussed in Section 4.3) sparked Singapore's interest in developing a full-fledged Green Mark (BCA 2010) rating system for tropical lab buildings. Other methods for institutional relationship building include researcher exchanges at educational institutions or national labs, shorter-term collaborations such as conducting joint workshops, or even writing collaborative reports.

3 CASE STUDY BACKGROUND: CLEANTECH TWO PROJECT

CleanTech Two (CTT) is the second building in CleanTech Park, Singapore. JTC Corporation, a government-owned contracting company, is developing the building, and indeed CleanTech Park, as part of a partnership with Singapore's Economic Development Board (EDB) to attract "a core nucleus of cleantech activities to serve as an epicenter for research, innovation and commercialization in clean technology" (EDB 2012). CleanTech Park is intended to serve as a large-scale integrated "living laboratory" for test bedding and demonstration of system-level clean technology solutions.

In the press release announcing the building's groundbreaking, JTC Corporation describes CleanTech Two (2012):

> CleanTech Two will be specially configured to support research and prototyping activities that require heavier loadings, higher height clearances and greater electrical power requirements. In addition, in order to cater to the growing demand for cleantech incubation facilities, CleanTech Two will feature fitted laboratories and offices.

CTT is a 22,300 m^2 core and shell building intended for multi-tenanted office and laboratory use. The design team developed an energy efficient concept and included renewable energy plans in support of the Green Mark Platinum certification goal. In particular, designers focused on daylighting, natural ventilation, and building orientation to manage energy demand. The space will be rented to various tenants, with the Advanced Remanufacturing Research Centre (ARTC) acting as the anchor tenant for the space and occupying the ground floor and potentially the first and second stories (Ong 2012).

4 SCIENTIFIC PLANNING SUPPORT (SPS) TEAM DESCRIPTION

Nanyang Technological University (NTU) and the Austrian Institute of Technology (AIT) conceived the Scientific Planning Support (SPS) team as a partnership that would support achieving aggressive energy targets. We describe the composition of the SPS team, their role and outputs in the context of the CTT project in the following sections.

4.1 ROLES OF SPS TEAM MEMBERS ON CLEANTECH TWO (CTT)

The Scientific Planning Support (SPS) team comprises three entities on the case study considered: Nanyang Technology University (NTU) in Singapore, the Lawrence Berkeley National Laboratory (LBNL) in the United States, and the Austrian Institute of Technology (AIT) in Austria. Figure 2 illustrates the roles of each of these entities on the CTT project. NTU serves as a liaison with JTC in Singapore, as well as with other members of the SPS team. Moreover, NTU has experience with local best practices for energy-efficient buildings. LBNL provides expertise in U.S. best practices for energy-efficient buildings, developing design concepts relating to low-energy laboratories and windows as well as indoor environmental quality, and measurement and verification (M&V) strategies for CTT. LBNL was also responsible for facilitating early charrettes and workshops to align designers, builders, and the SPS team around a common set of project goals. Finally, AIT provided technical expertise in European best practices for energy-efficient buildings, in the form of developing design alternatives and providing input on LBNL-developed design alternatives. AIT's primary role, however, was to develop simulation capacity at NTU, which took the form of training NTU researchers to build simulation models of the CTT building. Simulation results informed decision-making on the project, especially in terms of how various alternatives contributed to the building's Green Mark energy performance target (BCA 2010).

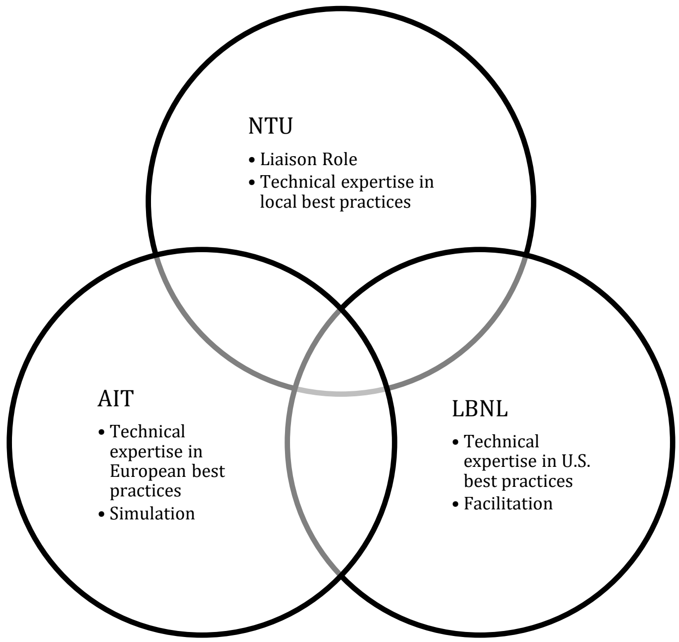

Figure 2. Roles of the SPS team members on the CleanTech Two project

4.2 ROLE OF SPS TEAM ON CLEANTECH TWO (CTT) BUILDING

The SPS role varied over three phases of CTT design, namely, conceptual and schematic design, design development, and construction documents. With each successive phase, more responsibility was transferred to NTU, while LBNL and AIT transitioned to "behind-the-scenes" roles, supporting the project on an as-needed, rather than continual, basis.

4.2.1 SPS Role During Phase 1 (Conceptual/Schematic Design)

The SPS Team was hired by JTC Corp. to "push the envelope" of energy savings for CTT. Though JTC committed to Green Mark Platinum as a goal early, they wanted to achieve this target with innovative technological and operational strategies, in support of the "living laboratory" concept for CTT. By bringing in international expertise, JTC sought to broaden the range of design alternatives considered.

Figure 3 illustrates how the SPS team engaged in different phases of the design process. During goal setting, the SPS team worked to translate the Green Mark performance goal into a numeric goal. The SPS team also worked with the design team to adopt an integrated approach to building system design. Thus, rather than setting system-level energy goals, the design team maintained flexibility and opted to make certain systems more or less efficient depending on design, construction, or operational constraints. For instance, JTC wanted to offer tenants great flexibility through a plug load capacity of 1,000 kW/m^2, so the design team created an aggressive daylighting plan to offset the large plug loads. During analysis and development (aka, conceptual/schematic design), the SPS team reviewed international best practices to develop a set of design recommendations for CTT. Promising energy efficiency measures (EEMs) were simulated to predict their impact on CTT's energy consumption. Though many international best practices were reviewed and considered for inclusion in the project, perhaps the richest dataset was from the Laboratories for the 21st Century (Labs 21) toolkit that described different low-energy strategies and technologies for laboratory buildings (Labs21 2008; Mathew et al. 2004). Once literature and best practices were reviewed, the SPS suggested specific EEMs for inclusion in the project. All Labs 21 EEMs remained as considerations, since these were in some sense pre-customized for the CTT building type. Additionally, EEMs focused on reducing energy consumption in the air conditioning and mechanical ventilation (ACMV) end use and the equipment load end use were maintained, as these were projected to be the largest energy consumers on the CTT project. Finally, the SPS team emphasized the role of Measurement and Verification

(M&V) for maintaining energy savings over time (e.g., (Brown et al. 2006; Mills and Mathew 2009).

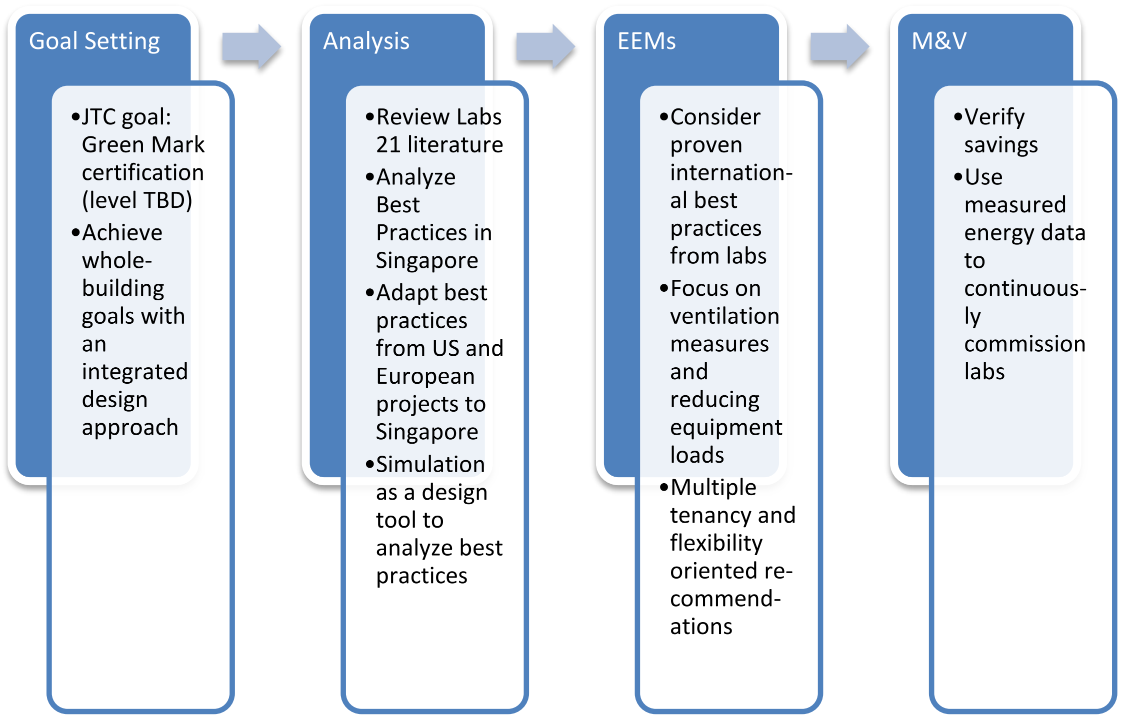

Figure 3. Roles of the SPS team during different phases of the CTT project

4.2.2 SPS Role During Phase 2 (Design Development)

During phase 2, the SPS continued their simulation efforts based on the design team's preliminary design for CTT. Further, the SPS team assisted JTC in comparing alternative EEMs. Finally, the SPS team completed their design analysis, based on the preliminary design from the design team. The SPS team presented these results and discussed them with JTC and the design team in two design review events during Phase 2, namely the Computational Fluid Dynamics (CFD)/Energy Simulation Review presentation and the second SPS Design Charrette (the first was part of Phase 1).

Beyond specific work on the CTT project, Phase 2 also included an exchange program between NTU and AIT to seamlessly transfer the technical expertise and knowledge regarding CFD, energy modeling, and energy simulation from AIT to NTU. This exchange program supports preparing NTU—the primary project executer for Phase 3—to better perform the tasks required for Phase 3.

4.2.3 SPS Role During Phase 3 (Construction Documents)

Starting from the results of Phase 2, Phase 3 focuses on developing construction documents (the final stage of the design development domain). Specifically, the SPS team (largely represented by NTU) further developed detailed analysis to determine the optimal set of design options (multiple concepts were developed in Phases 1 and 2) and finalize the technologies for CTT's public demonstration space, the iSpace.

4.2.3.1 Building Design Optimization

In Phase 3, NTU conducted a series of iterative design analyses to describe design scenarios and their merits to assist the design team in developing an optimal design solution that meets all required criteria (e.g., energy and cost constraints). These scenarios include a baseline building design and a set of alternatives with variation from that baseline. NTU selected the simulation tools (e.g., TRNSYS, eQUEST, COMFEN, and FLUENT) to perform a series of analyses based on the JTC-prescribed performance indicators for various building systems. (Note these performance indicators are in flux at the time of this publication, and are thus not presented here.) The results of these analyses allow JTC, and the design and SPS teams to better understand the predominant building loads within each scenario and the whole-building performance of each scenario. Finally, the SPS team worked with JTC to develop a green lease during this phase as a means of optimizing building performance. Green leases “align the financial and energy incentives of building owners and tenants so they can work together to save money, conserve resources, and ensure the efficient operation of buildings” (GreenLeaseLibrary.com 2012). JTC views the green lease as a means of optimizing building performance: the lease supports energy efficient behavior and, in turn, the Green Mark performance target. NTU worked with JTC to ensure efficiency requirements in the green lease are readily implemented in Singapore without a drastic increase in capital cost.

4.2.3.2 iSpace Technologies

At the first design charrette, the SPS team proposed 20% of the CTT building implement advanced technologies to illustrate their effectiveness in Singapore. Essentially, this innovative space (iSpace) will serve as a demonstration facility for future low-energy, high-performance buildings in Singapore. The iSpace includes interior and exterior areas, as low-energy strategies and technologies exist for both space types. The SPS team and the design team proposed a number of iSpace technologies. Table 1 lists some of the technologies explored and proposed for the iSpace. Items listed in the “Other Technologies Proposed” column were proposed but were not considered for implementation in CTT. Beginning in Phase 2, and continuing in Phase 3, the SPS and design teams worked with JTC to review technologies listed in the “Technologies Explored” column (Table 1). Specifically, the SPS and design teams conducted iterative and climate-based evaluations of these technologies, examining life cycle costs and performance, cost-effectiveness, durability, and efficiency of maintenance. Simulation tools (including energy simulation, daylight simulation, and CFD) furthered the performance evaluation of these proposed subsystem technologies.

Table 1. A Sample of Explored and Proposed Technologies for the iSpace

Technologies Explored	Other Technologies Considered
Low energy fume hoods	Wireless sensor networks
IAQ dash boards	Under-floor ventilation
Stratified cooling	DC powering
Cool roof coating	Solar Light Tubes
Radiant cooling	Neuro PMV (Predicted Mean Vote) controls for air conditioning
Smart parking luminaire	ETFE material to cover courtyard common space

After completing their reviews, the project team selected a Lab Indoor Air Quality (IAQ) Control/Monitoring system, stand-alone low-energy fume hoods, and a smart parking structure luminaire system for the iSpace. These technologies will be demonstrated in landlord-managed areas (e.g., fitted labs, fitted offices, and common areas) of CTT. They will improve CTT's building performance and energy efficiency while also serving as a public showcase of innovative low-energy building features.

4.3 Outputs of the SPS Team – Support for Achieving Building Energy Targets

The SPS team developed and simulated many low-energy design alternatives, as illustrated in Figure 3. This work helped to improve the simulated energy performance for the building from 25% reduction relative to code-compliant baseline to 37% reduction from the same baseline. In addition to work developing, simulating, and evaluating the design alternatives, the SPS team helped to shape the design process to facilitate an integrated approach to building design and operations, as well as to align the design team around low-energy design alternatives. To capture these contributions, the SPS team has prepared a series of presentations and reports that can be used on future projects to inform low-energy design. These materials may be of particular note for future CleanTech Park developments, as they are framed in the context of CleanTech Park.

Figure 4 illustrates the approach for low-energy laboratory design developed by the SPS team. Note that it considers design and operation when developing EEMs to immediately focus the design team on ensuring persistence of savings. Though the SPS team considered specific end uses are considered, the emphasis is on integration of strategies across end uses, including integrated systems design, DC powering of various building systems, ensuring indoor environmental quality across end uses and throughout the building, metering and monitoring across end uses, and finally, continuously commissioning the whole building. Specific recommendations for the CTT building are outside the scope of this paper, but these are discussed in the SPS report.

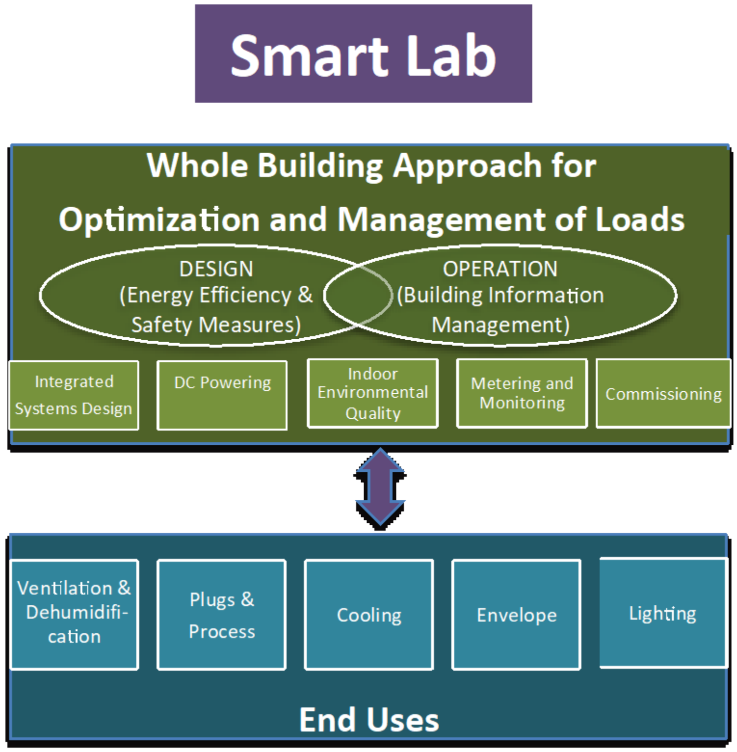

Figure 4. The whole-building approach to low-energy laboratories in Singapore developed by the SPS team

5 DISCUSSION

Though the case study presented in this paper describes the role and efforts of the SPS team on a specific project, SPS teams show promise for achieving energy efficiency on other projects as well. Additionally, broader collaborative models show promise for achieving energy savings. We enumerate the benefits of SPS teams, specifically, below:

Capacity Building: SPS teams may only engage with design teams for a short time, but they can introduce a wealth of resources in that time that can broaden the scope of inquiry for the design team on both the project the SPS engages on and future projects. Over time, this knowledge can be transferred to other design teams. This was demonstrated through the NTU/AIT exchange that built simulation capacity in NTU. SPS teams may be most strategically deployed in Brazil, India, China, and other nations that are going through construction booms, as it is often easier to design efficiency into new buildings than retrofit existing buildings to improve efficiency.

Challenging status quo: On the CTT project, the SPS team was brought in to "push the envelope." Often, fresh perspectives contribute to developing new ideas and realizing synergies between systems. As with capacity building, challenging the status quo will lead to deeper energy savings on a single project in the near term (namely, the project the SPS engages in), and should lead to deeper energy savings across projects over time, as networks of design teams challenge the status quo on successive projects. Higher-level collaboration models may also support challenging the status quo, though to a lesser extent, as "status quo" for efficient buildings may not apply at the national level where these collaborations tend to develop.

Developing new resources: As the SPS team brings best practices from their collective experience to a project, they will likely develop new resources for low-energy design and may make explicit knowledge that was previously tacit. For instance, the SPS team for CTT prepared reports that enumerate Green Mark requirements and recommend specific strategies to achieve these requirements. These resources can aid in deploying the findings from the SPS team and can enable energy efficiency in other buildings.

Though the SPS team we describe is made up of entities from different countries, SPS teams can also be effective when they are not international. For instance, an SPS team with expertise in low-energy design and operations for a given building type would be able to realize the benefits described above in their own country as well as internationally.

Moreover, as design teams work with SPS teams, they will gain experience in providing technical expertise themselves, in turn, they can form their own SPS team and provide consulting services to their colleagues at other design firms, continuing knowledge transfer and broadening deployment.

While international composition is not critical for an SPS team, an SPS team with a breadth of expertise will offer most value. The role of an SPS team is to offer innovative solutions for the whole building, supporting an integrated approach to building design and operations. Thus, an SPS team can provide richer design assistance if they have technical expertise in a range of building systems rather than expertise in a single-system, e.g., an MEP consultant or a façade consultant.

Similar trends exist for other collaboration models. The broader the expertise, the more creative the solutions the collaborators can develop. As the collaborations become broader in reach and scope, international makeup essentially becomes a requirement. That is, collaborations to develop new policies and effect changes in building energy efficiency at the regional and national level will likely require international perspective. A group of national experts in building energy efficiency can certainly develop policy recommendations and make suggestions about achieving energy savings at the national scale, but they will likely bring the bias of their country's policy norms. We argue an international team may develop the most innovative solutions because they can borrow from best practices at an international, rather than national, scale.

6 CONCLUSION

Collaborative models support building energy efficiency at various scales and with various impacts. Multi-lateral programs may support far-reaching deployment of 5% energy savings through new incentive programs, labeling programs, etc. Governmental collaborations also support energy savings, typically through new policies or introduction of new technologies within a particular environment. These collaborations may yield deeper savings than multi-lateral programs at the building level, but the overall impact (in terms of gross savings) may be less than that of multi-lateral programs, since the reach may be smaller. Finally, institutional collaborations, like the SPS team discussed in this paper, support achieving deep energy savings in a single building, both through technological and operational strategies. Moreover, they support an integrated approach to building design and operations that affects the design process. Design assistance teams, similar to SPS, show promise for increasing the scale of deployment for low-energy building design and operations through capacity building, challenging the status quo, and developing new resources. Building owners considering SPS teams may opt to engage them first on high-energy-intensity building projects, where SPS teams can provide most value, as these building types generally require more innovative solutions to achieve performance relative to their less-energy-intensive counterparts.

We argue a balance of each of these collaborations best supports energy savings. Similar to taking both a top-down and bottom-up approach to energy management at the building level, engaging in each of the collaboration models presented in this paper at a national level effectively pushes multiple levers to manage energy. Through the United

Nations, the International Code Council, and other international groups, national governments have many opportunities to engage at the multi-lateral program and governmental collaboration levels. However, institutional collaborations may be harder to track, as these may develop more informally. If governments and institutions across continents continue to collaborate, energy efficiency strategies, technologies, and programs can evolve worldwide that address climate change and energy demand issues in support of a more sustainable built environment.

7 ACKNOWLEDGMENTS

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