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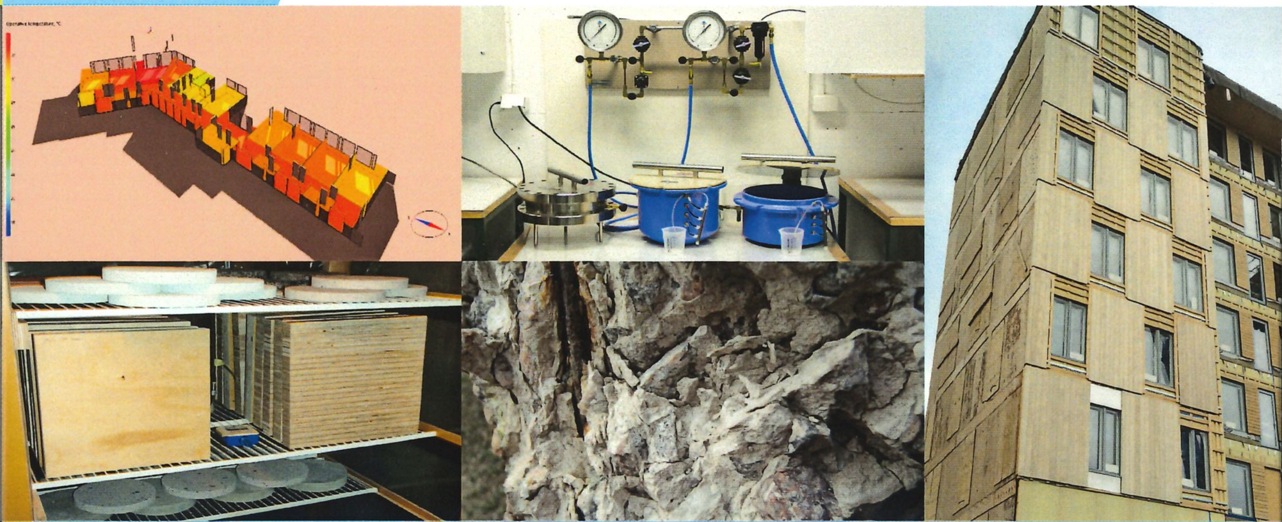

Tampere 2017

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Keynotes

Innovation Strategies for the Built Environment in Research, Practice, and Teaching

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P+ Studio, London, UK

Abstract

This paper presents various strategies for innovation in architecture and engineering using case study projects from the portfolio of P+ Studio, as part of the keynote speech, "Innovation Strategies for the built environment in research, practice, and teaching." The presented work is seen in the context of required industry change and better synergies between various built environment industry sectors.

1. Introduction

In the field of architecture and the built environment, the creation of technologically progressive, environmentally ground breaking or economically disruptive solutions for contemporary urban problems have been compromised by slow innovation cycles [1]. While it is acknowledged that we need radical change in order to address issues of energy use, climate change, and building life cycle, we are facing limited progress in all areas, from design to construction, to the operation of our built environment.

Massive increases in urbanization have led to the compounding impact of heat island effects, compromised air quality, unprecedented demand for infrastructure and transportation, energy supply, increased burdens on water and waste systems, [2] among others. Solutions include the transformation of existing urban centres through densification and the implementation of retro-fit solutions, the rapid expansion of existing or the creation of entirely new city developments. In addition to current trends in construction, the existing building stock is comprised of increasingly sophisticated, interconnected, high value assets. Buildings completed today are going to be with us for decades to come, with ambitious current and more drastic future standards governing the demanding development of new solutions throughout all life cycle stages.

Driven by multiple policy and practice as well as environmental trends, sustainable design strategies are no longer a choice, but a serious professional obligation. Sustainability is acknowledged as a key driver for needed innovation, as there is simply "no alternative to sustainable development" [3]. It is important that designers from all disciplines understand the mandate to engage with a sustainable practice, and appreciate this method as an enormous opportunity to collectively develop new design strategies, urban typologies, and advanced building technologies —environmentally friendly, integrated solutions that address energy conservation and the complexity of holistic systems thinking.

These are all complex questions that can only be solved by radically altering the way in which we not only work and practice, but also educate the next generation of creative thinkers. Answers can only be met by overhauling the current outdated system of disciplinary silos in professional education, as well as the relationship between all built environment stakeholders. Built environment professionals are members of a risk-averse community of practice that cannot tolerate failure for policy, safety, operational and financial reasons, amongst many others.

However, a design experiment cannot produce innovative solutions, if failure has been excluded to begin with. Built environment professionals from all disciplines are greatly positioned to innovate. Transient in between the arts and sciences, architectural designers are oftentimes challenged to merely create new versions or variations of what we know, and how it is likely to perform—to change this, it will require commitment and input from all involved parties.

We need to further consider established models and relationships of development, deployment and the dissemination of new knowledge, as well as key objectives that differ between academia and industry. This paper will examine a series of case studies from the portfolio of our practice P+ Studio, which exemplify these potentials and offer a strategy for rethinking the design process itself on various scales.

2. Bridging the gap between research, teaching, and practice

For many architects, an education that is multi-disciplinary in nature and offers collaboration between architecture, science, engineering, and arts, can serve as the foundation for future innovation projects. In order to ensure a robust future with infinite potential to alter the way we design and build our cities, we need to instill a methodology for innovation as well as interdisciplinary research in the new cohort of built environment professionals. Leading to the appointment as Interdisciplinary Design for the Build Environment (IDBE) faculty at the University of Cambridge Institute for Sustainability Leadership, we have embraced this methodology in the establishment of our practice through work that lies at the intersection of research based design, industry collaboration, and teaching. We have invested in the latter by adapting our office framework to various forms of education, from foundational academic to continued professional educational offerings.

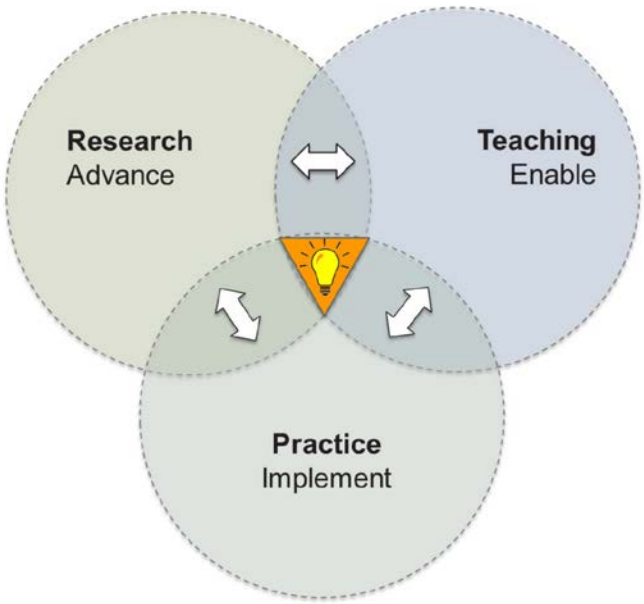

Figure 1. P+ tripod model of relationships and overlaps between research, teaching and practice.

Collaboration potential lies at the direct intersections of all three areas of research, practice and teaching. However, we believe that the greatest innovation potential lies at the overlap of all three (figure 1). We can advance knowledge and the industry through fundamental and applied research, include students and professionals alike in shaping the next generation of practice models, and test and deploy novel ideas with support from industry. It is hereby crucial to understand drivers and obstacles in the individual sectors and opportunities that the created overlaps provide. Our office P+ Studio is involved in all areas of design, interdisciplinary collaboration and teaching, and we use this constellation to advance our research agenda. We therefore propose that this collaborative model may serve as a testbed for innovation and design.

3. Fostering innovation through interdisciplinary teaching models

Our teaching methodology presents opportunities for exchange between design community, consultant base, industry and academia. Our academic and consulting scope includes the development of new interdisciplinary curricular developments for a range of high ranking academic institutions, as well as progressive organisations like the UK Green Building Council.

As studio instructors, we convey the principles of a critical thinking approach and support a design attitude that allows the students to develop their own language, while developing their abilities to apply this methodology to any given design task in the future. We believe that design emerges from a strong methodology and a multi-faceted systems thinking, while addressing valuable and established aspects of design theory. The technological aspects of this approach should therefore enhance the set of observations and methodologies for an optimization of performance and efficiency.

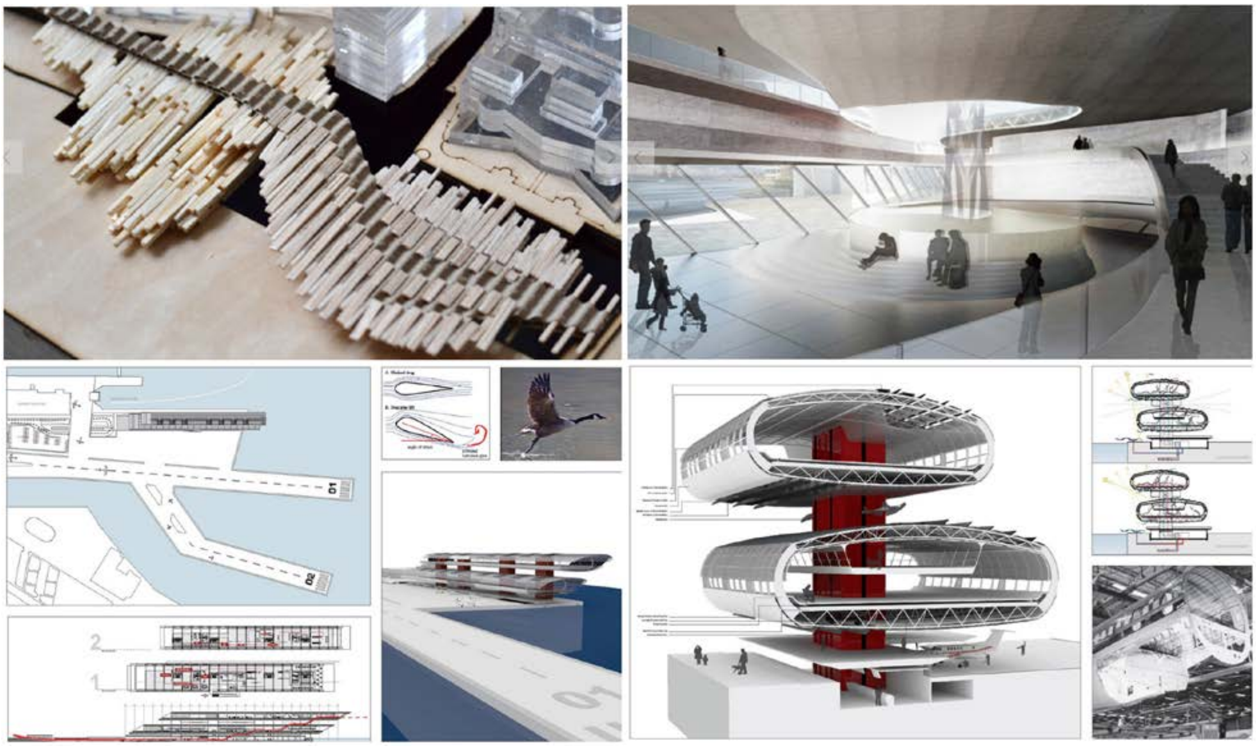

Figure 2. Design Studio teaching examples from Syracuse University School of Architecture.

Our studio briefs typically involve projects that cross the boundary between architecture, art and engineering, and draw from technological criteria and performance aspects as an additional decision making tool set (Figure 2). Our model instils current research practice or trends within the studio parameters of a design problem.

In a design project, we are looking for the creation of 75% feasible and practical solutions (base knowledge), while challenging the students to dedicate 25% to speculation (experimentation). The course offering therefore enables and unlocks innovative solutions for complex issues at a conceptual level, which can later be implemented in real projects.

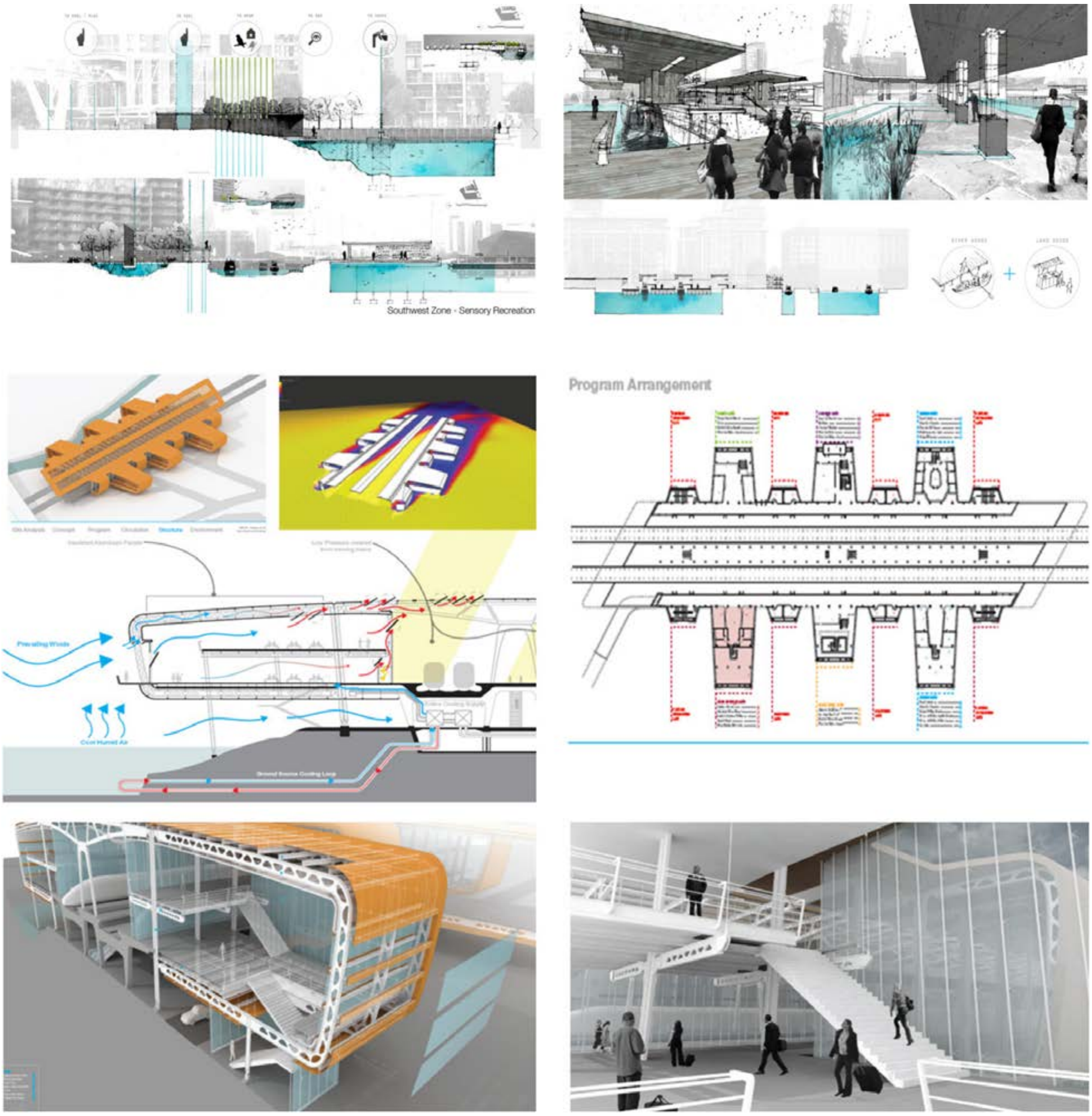

Figure 3. Examples of infrastructural and ecologically themed studios. Top: Floating village in the London Victoria Docks. Bottom: Ecological transport hub.

Design studio challenges are nested in a larger infrastructural or ecological context, which allows students to understand interrelationships in terms of scale and function (Figure 3). In addition, through workshops and seminars, we develop cross-disciplinary agendas that bring together architecture and engineering students from different cultures and academic levels. In a Design-Build studio setting or through funded academic research, we have tested new architectural ideas supported by engineering faculty and students through systems design, performance simulation, prototyping, and lab testing.

3.1 Case study: Botanical Air Cleaning Wall System

One such project is the NASA technology informed development of a novel modular green wall system. As professors at the Syracuse University School of Architectutre, New York, we developed the Botanical Air Cleaning Wall System together with Dr. Jensen Zhang, professor and director of the Building Energy & Environmental Systems Laboratory (BEESL), Department of Mechanical and Aerospace Engineering, Syracuse University (SU).

As part of the development of the Air Cleaning Technologies (ACT) prototype designed by BEESL and funded by NYSERDA (New York State Energy Research and Development Authority), the wall system is based on the Wolverton filtration technology, a NASA based spinoff technology, which presents a unique opportunity for developing and deploying such an integrated air cleaning device. The device uses a plant root bed of activated carbon, porous shale pebbles, microbes and a wet scrubber to remove Volatile Organic Compound (VOC's) and radon from the air in tightly sealed buildings [4].

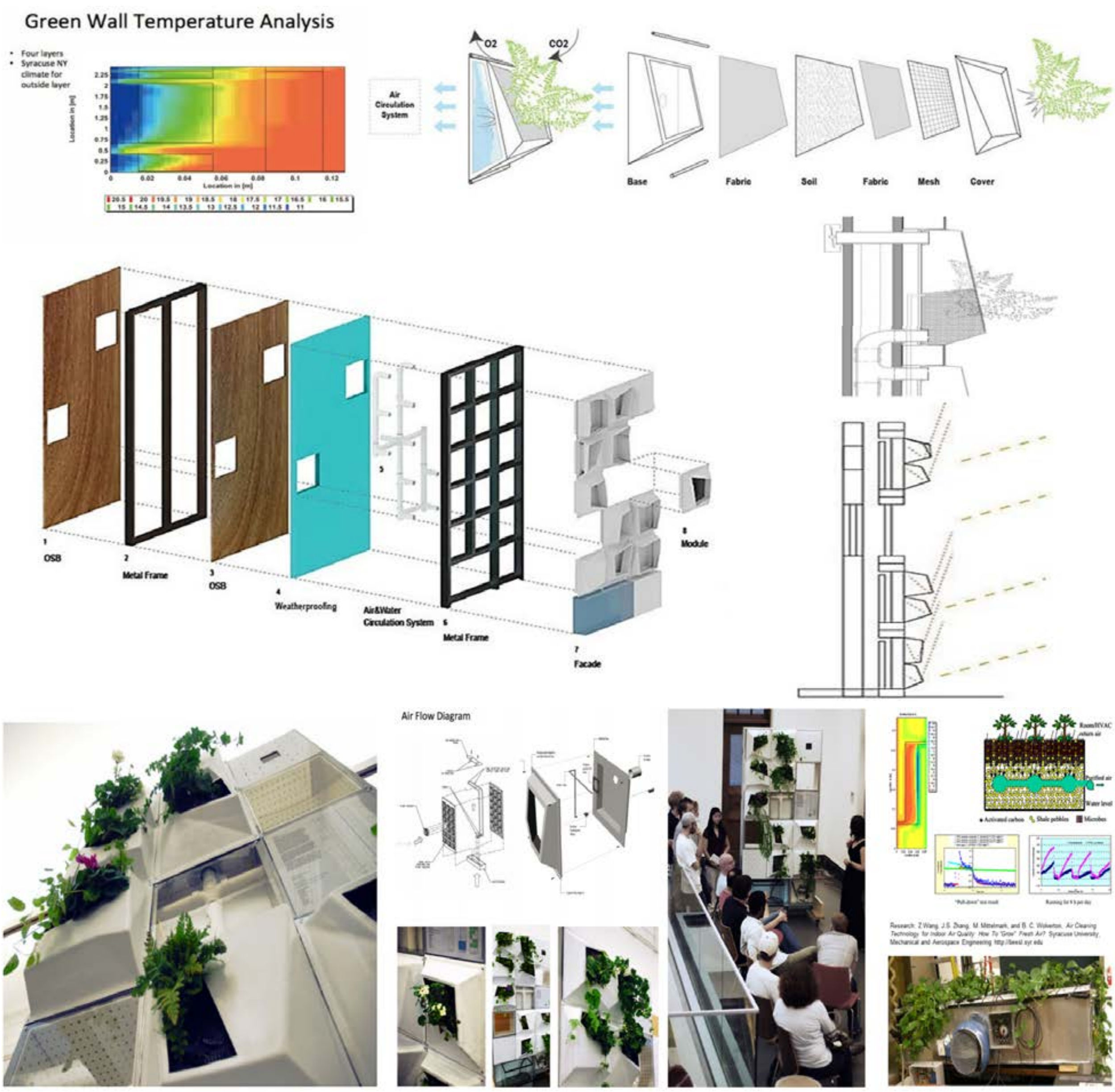

Figure 4. Botanical wall system for air purification.

Unlike conventional green wall systems that are merely screening off the exterior wall, this modular assembly is comprised of a panelized hydroponic planter system, proposed as a permeable part of a typical insulated residential or commercial wall build-up. The current prototype filters air through the plant root bed through an air duct system which brings the refreshed air indoors. The required irrigation system can function as a humidifier during warm and dry seasons, and further improve Indoor Environmental Quality (IEQ).

The current prototype was constructed and designed through a collaborative course with SU Architecture and Engineering students, ranging from the undergraduate to graduate and PhD level. As a case-study, the project challenged the mixed group to explore collaboration not only in the design and construction but also in the simulation and monitoring of the operational wall. The process effectively served as a teaching model for an advanced, research based professional relationship between engineers and architects. Students learned to not only communicate their ideas across disciplines, but also to compromise and effectively implement one another's diverse skill set within a limited budget and tight time constraints. This learning methodology for cross disciplinary cooperation forms the foundation for an innovation driven framework.

3.2 Case study: Self-Sustaining Street Light

Another example of innovation-based research and teaching in the renewable energy sector is the patented product development of a Self-Sustaining Street Light, which combines solar and enhanced wind powered systems, co-generation and battery storage, and highly efficient optically enhanced LED lighting technologies in the design for an off the grid street light (Figure 5).

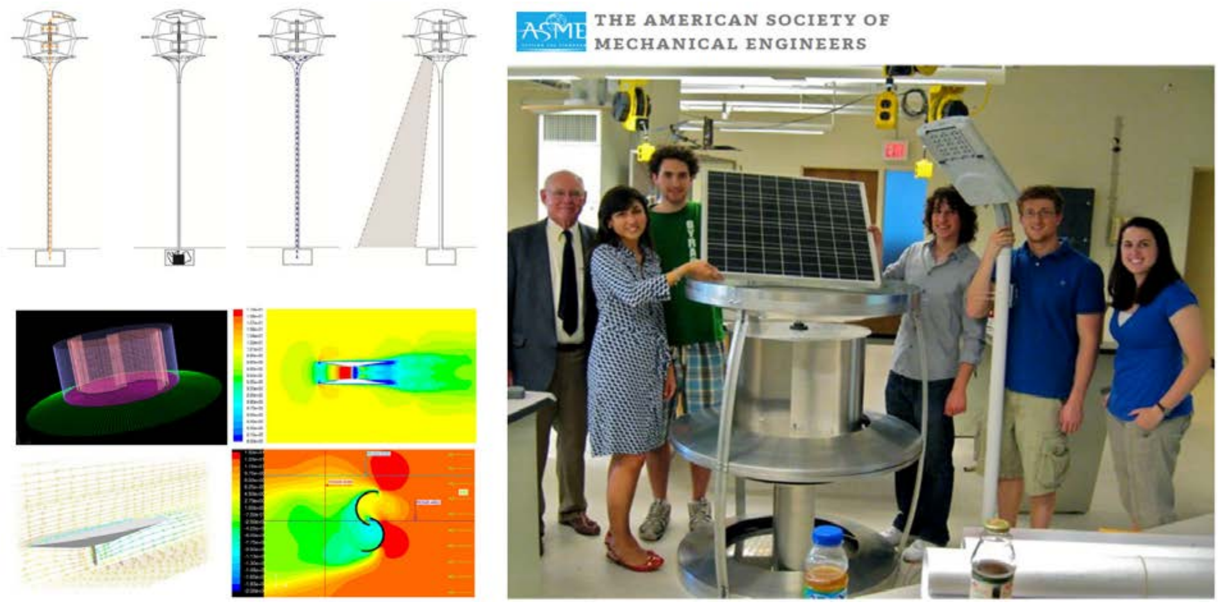

Figure 5. Award winning Self-Sustaining Street Light development.

The project is based on a concept that was developed in collaboration with Dr. Thong Dang, professor at the Department of Mechanical and Aerospace Engineering, Syracuse University. The patented innovation (Patent Registration Nr. US 8.282.236B2), developed for the optimized operation of Vertical Axis Wind Turbines (VAWT) in the built environment, introduces a novel efficient design form that can increase wind energy harvesting capacity up to 250%. System startup requirements are reduced for efficient operation at lower wind speeds compared to the base configuration, which is resulting in extended operational hours and increased system efficiencies.

The process included all steps from securing seed and development funds in form of a research fellowship from the New York Center of Excellence for Energy and Environmental Systems, to idea generation, interdisciplinary design studies, engineering and performance optimization in a senior design project with architecture and engineering students, proof of concept, securing additional funds for the patenting process, establishing industry collaborations, securing funds for commercialization efforts, and directing prototyping and lab testing. Initiated through a 4th year engineering capstone study project, the student cohort was comprised of master level engineering students, supported by PhD level teaching assistants, and graduate research assistants from the architecture faculty. The student project was presented at various conferences and honored with the Farnell Design Award by the American Society of Professional Engineers.

The project was further supported by SU's Technology Transfer Department for the patenting process, resulting in both utility and a full US patents. Select design students and PhD researchers staid involved in every step of the prototype development. The project served as a test bed for sustainable product development and real-life applications. The ubiquity of the innovative design in particular led to scalar applications of the patented geometry. Through P+ Studio, we further developed this proven innovation through the design for an energy-plus building, effectively applying university-led research to a new experimental practice-based architectural prototype.

4. Process optimization for building design and energy plus operation

The ability to effectively recognize a principle and apply it to a new prototype (or in this case, a building), while challenging established typologies and feeding the loop of innovation, is another aspect of our integrated practice model. Our spinoff projects from our academic work have led to novel architectural solutions for construction as well as building operation.

4.1 Case study: The Turbine-House

The Turbine-House investigates the possibilities of the use of the patented efficiency principle in smaller scale residential, office or mixed use buildings (Figure 6). The patented principle behind this P+ Studio project was developed at the Syracuse Center of Excellence for Environmental and Energy Systems in New York in collaboration with Dr. Thong Dang from the Syracuse University School of Mechanical and Aerospace Engineering. Investigating the use of prototypical solutions in different scales, the Turbine-House is a direct spinoff project from the Self-Sustaining Street Light.

The building uses an augmented aerodynamic geometry which increases energy output while directly impacting building orientation, massing, and programmatic zoning. Numerous 2D and 3D Computer Fluid Dynamic studies have been used to facilitate the design and geometry optimization process.

The wind turbine is located at the top of the building for maximum wind exposure. Additional energy generating capacity is provided through a maximized sloped roof surface area that integrates a photovoltaic array and solar thermal heat exchangers. The compact circular building arrangement provides a good surface to volume ratio.

Figure 6. Turbine-House design and renewable energy systems integration.

Various passive strategies and hybrid building technologies have been applied to the design that further inform important design aspects like climate response, environmental zoning, as well as façade design and natural ventilation strategies. Given the circular arrangement, the building can be cost effectively assembled with modular components facilitating type and system standardization [5].

The design provides a sustainable, fully integrated 21st century building solution and represents a novel synergistic approach between advanced architectural design and environmental engineering, pushing disciplinary boundaries of traditional design practice.

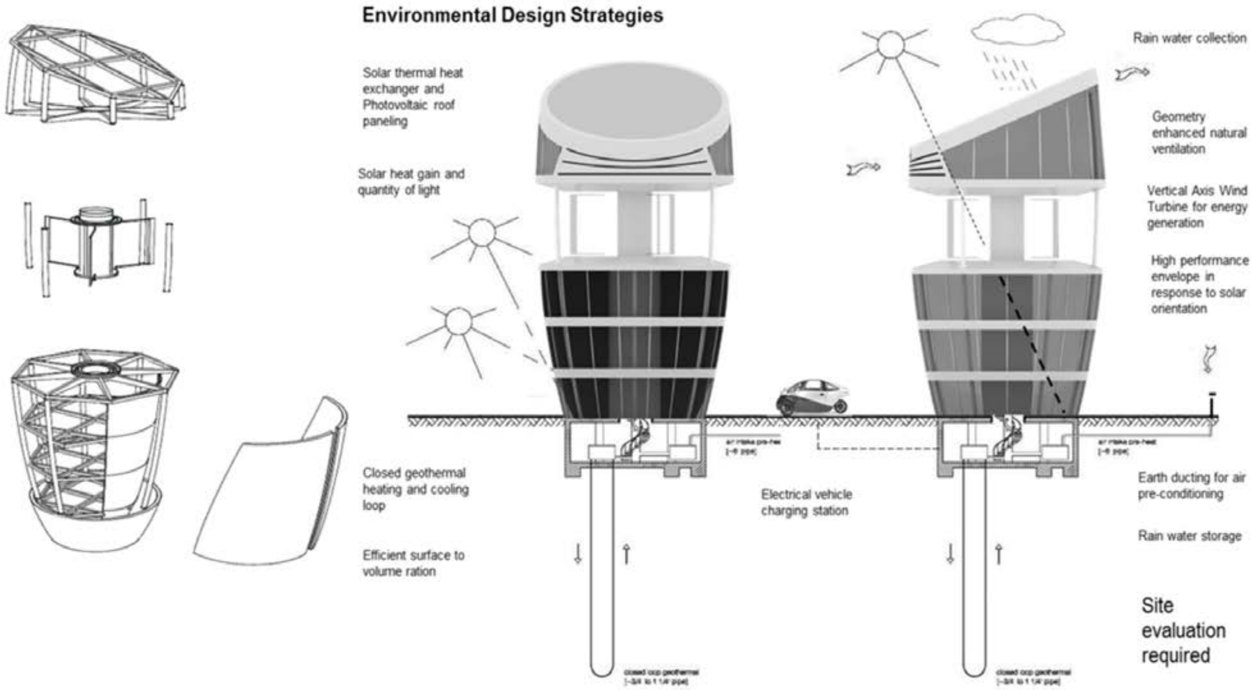

Figure 7. Structural and hybrid environmental design strategies for the Turbine-House.

The residence offers significant energy and cost savings for new development models of similar buildings in areas with weak or no infrastructure. It acts as an "architectural power plant" that feeds back into the grid, supports other neighborhood or site installations such as lighting and charging stations for cars (Figure 7). The building is an experimental prototype that can be optimized for a particular site, program and climate, while providing flexible open spaces with optimal lighting conditions and fantastic views to the exterior (Figure 8).

Figure 8. The Turbine-House as a dynamic living environment and "architectural power plant".

The building is an experimental prototype that can be further optimized for a particular site, program and climate context. The schematic design of the project has been concluded in preparation for a client pitch that aims at the further development and realization of the project as a next step.

4.2 Case study: The building as a living lab for industry and academic collaboration

Figure 9. New sustainability investments: Wujin Green Building Industry Development Zone.

Exemplary of our approach towards built work is the P+ Demonstration Building in China's first accredited Green Building Expo Demonstration and Industry Development Zone (Figure 9). This experimental project was commissioned by the Chinese Government, designed in an interdisciplinary group between academic and industry professionals, and built in close collaboration with companies from the US and China. The building opened in late 2015 as part of the 8th International Green Building Conference and is currently subject to shared research with several university partners and the International Energy Agency (IEA EBC Annex 68). The project is designed as a living lab for systems and performance research by both academic and industry entities.

The newly established development hub in Changzhou is the first of its kind, promoted and accredited by the Chinese Ministry of Housing and Urban-Rural Development. Aimed at promoting sustainability and innovation in construction and manufacturing industries, the zone has already attracted major global industry leaders such as Saint-Gobain, Siemens, Bosch Group, General Electric, and the China National Building Materials Group, amongst many others. Academic relationships have been formed with Nanjing University, Zhejiang University, and Southeast University.

The 600m^2 mixed use building is an experimental prototype that features auditorium and exhibition spaces, offices and residential areas that allow for the testing of a range of industry standards and the demonstration of different green building technologies. The building functions as a laboratory for the implementation and quantitative evaluation of new ideas, serving as a physical manifestation of our design and collaboration ethos. Conceptualized as a platform for exchange, research and interdisciplinary teaching, the building was awarded the second highest rating from China’s Green Building Design Label.

Figure 10. The P+ Demonstration Building: north –east corner with vertical gallery and external platforms and south-east corner with smart louver systems and ‘plug and play’ facades.

With regards to the environmental qualities of the architecture, the compact design of the building provides good surface to volume ratio, provides self-shading overhangs, takes advantage of adjacent water bodies for evaporative cooling combined with monitored natural and hybrid ventilation for occupant comfort. The building is an open ended system in itself that features distinct building zoning and envelope strategies.

The south facade, with its overhang design and smart louver systems is designed to control optimum indoor environmental quality. Responsive façade systems at the east prevent overheating and provide balanced lighting conditions, while circulation spaces at the north act as an environmental buffer zone (Figure 10).
Greeting visitors with its distinct design and located in the central axis of the park, a journey through the building provides a unique experience with exhibition areas and viewing platforms at all sides that provide great views to the rest of the park. As a flexible framework for testing, the south façade can be upgraded with a range of renewable energy and environmental control systems in a ‘plug and play’ fashion according to research needs and emerging technologies. As examples, Trina Solar’s transparent photovoltaic glass solar panels as well as air circulation and electrical monitoring systems are on display for testing and educational purposes.

A prominent feature of the building is the solar chimney, the first of its kind in the Jiangsu Province and designed to set new standards for the use of hybrid technologies in the Chinese market. The device provides naturally enhanced ventilation, reduces cooling loads during the warmer and provides passive heating during the colder months. Its performance is currently being analysed and tested as part of a collaborative study between Nanjing University, Syracuse University, and Zhejiang University.

The roof of the building is equipped with a solar PV array, a white roof for the reduction of heat island effects, and the only weather and climate monitoring station in the park that allows for IAQ measurements and a comparison between indoor and outdoor conditions.

5. Interdisciplinary workflow and collaborative research

The majority of our projects are a direct result of ongoing interdisciplinary relationships. As part of our research, we have begun to define and quantify the working methodologies as well as the management of interdisciplinary projects through various networks and digital structures. These methods have been developed and deployed in both professional and academic settings.

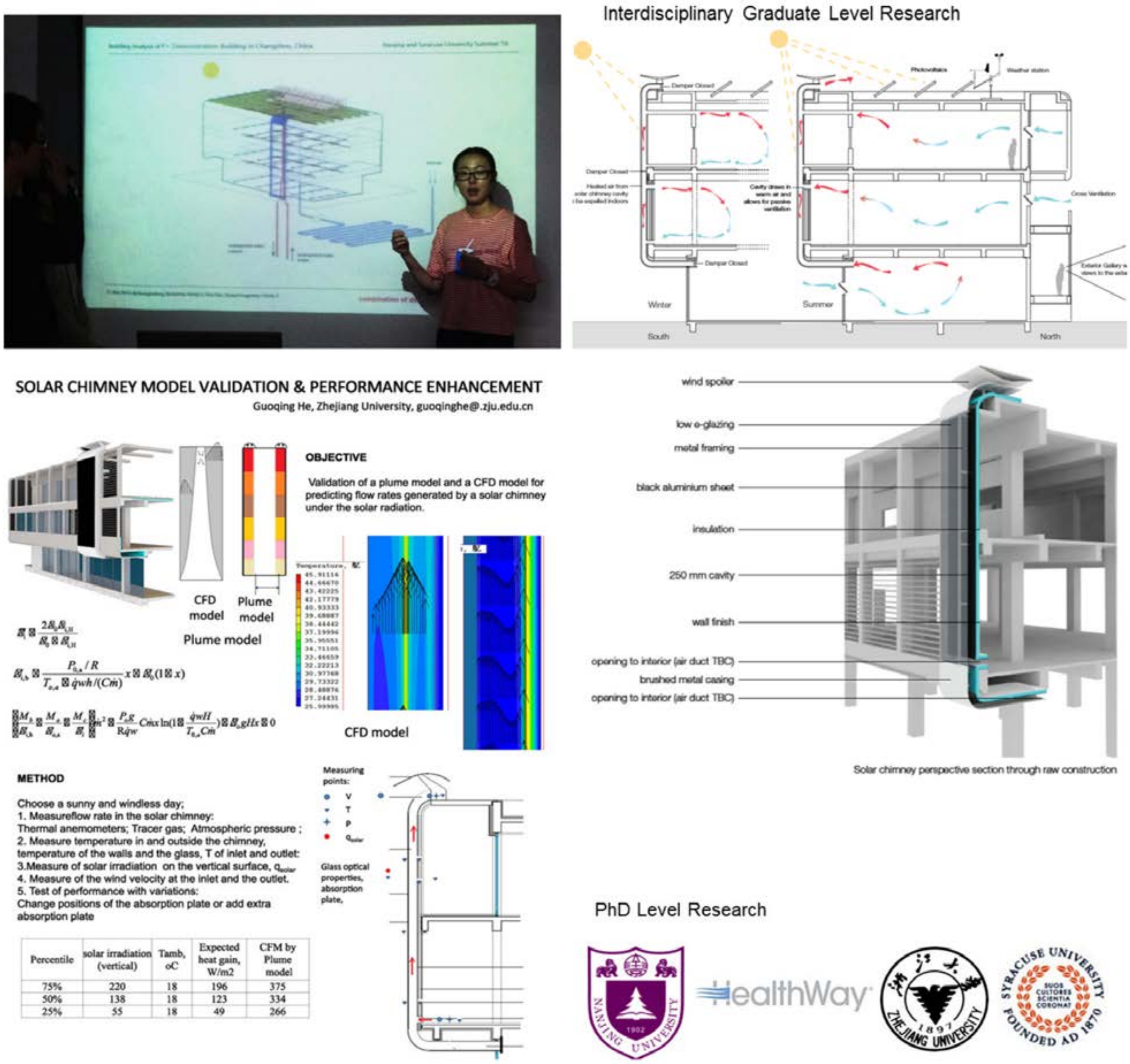

Figure 11. Research from the Syracuse University / Nanjing University Center for Sustainability.

5.1 International student collaborations between the USA and China

With participation from the USA and China we have used the Demonstration Building as a case study in an exchange program as part of the International Syracuse University - Nanjing University Center for Sustainability we established (Figure 11). The teaching methodology is based on our US Department of Energy funded development for an interdisciplinary digital design platform, the Virtual Design Studio.

In this capacity, students from design, architecture, and project management have the opportunity to work closely with peers from mechanical and aerospace, electrical, structural and environmental engineering. Following these initial successes, the center is now funded by both universities, has widened activities for exchanges between faculty members and other students, and formed a model for follow up initiatives at both institutions.

5.2. Virtual Design Studio

As part of our methodology for innovation, we have also developed a digital platform for interdisciplinary teaching and design development called VDS: Virtual Design Studio. VDS is a software platform currently under development in support of an integrated, coordinated and optimized design process of buildings and their energy and environmental systems (Figure 12). VDS is intended to assist collaborating architects, engineers and project management team members throughout from the early phases to the detailed building design development. The platform helps to facilitate the workflow and the processing of information in combination with appropriate, task based simulation tools targeted at performance optimization and coordinated systems implementation. It has been developed in collaboration with Dr. Jensen Zhang of Syracuse University, Lixing Gu from the Florida Solar Energy Center and Hugh Henderson, from the CDH Energy Corporation in New York.

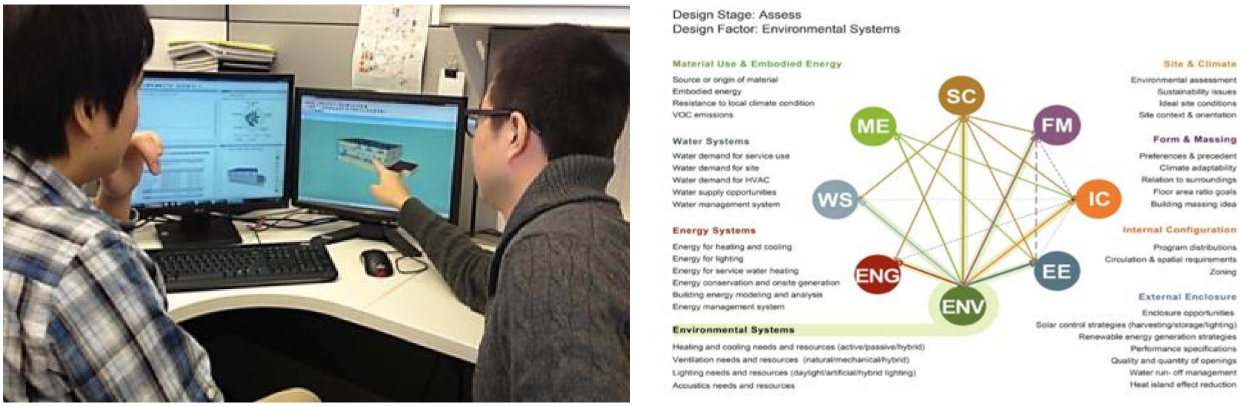

Figure 12. VDS Graphic User Interface and mapping of building system interdependencies.

We have implemented the program in a variety of university level seminar coursework, as well as visiting professorship appointments in China. While the platform development continues, we believe that the tools developed can be used in a variety of academic settings. With a simplified organization of all professional work stages (VDS-ADDAM structure), the interdisciplinary workflow is intended to also be tested in a professional design setting.

5.3 Case study in interdisciplinary collaboration and design: Guangxi Fangchenggang City Peach Blossom Bay Development

On an urban scale, we have tested the VDS platform ideas for the Guangxi Fangchenggang City Peach Blossom Bay Development, supported by the UTRC Climate Engineering Group at Tsinghua University in Beijing, China.

The Guangxi Fangchenggang City Peach Blossom Bay Development is a 400,000 m^2 mixed use urban development proposal in southern China, with a concentration in sustainable community planning and architectural design (Figure 13). Our project was the second-place winning entry, as part of a developer-commissioned international invited design competition. As a working model, the Guangxi Fangchenggang City Peach Blossom Bay Development seeks to address the above mentioned issues through an integrated collaborative working model between architects, urban planners and environmental engineers from professional and academic communities in the US and China.

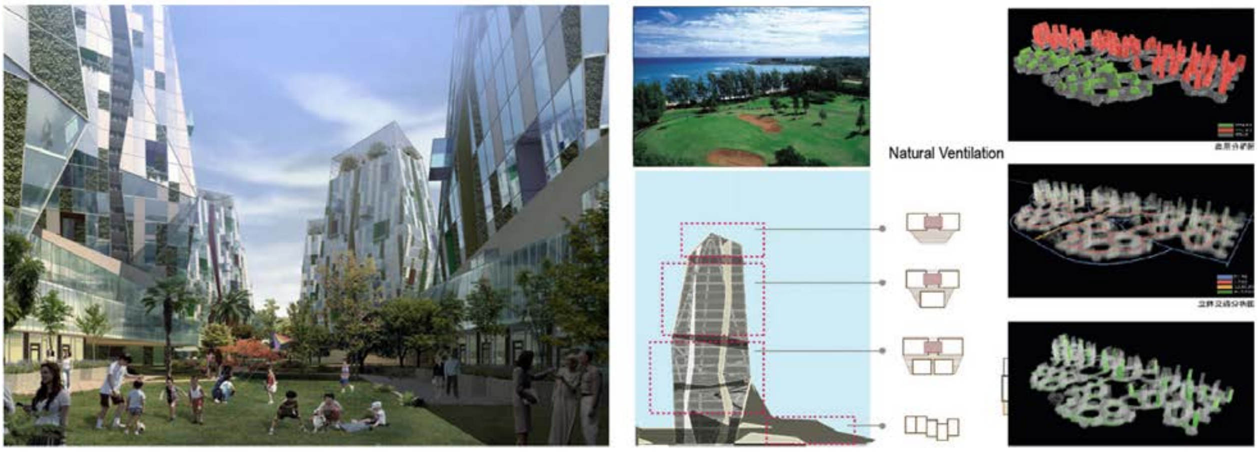

Figure 13. Peach Blossom Bay Development architectural design and urban massing studies.

The goals of the project were to:

- Identify possible new synergies in working methodologies between architects, planners and engineers, to streamline the design process and offer opportunities for ecological systems integration.
- Analyze how simulation technologies applied in the development affect planning strategies, site development aspects and architectural performance optimization principles for energy conservation and enhanced natural ventilation.
- Offer areas of design where further simulation may be warranted in the design process, focusing on urban design, infrastructural community planning and building component efficiencies (macro to micro, multi-zone and multi-scale investigations).
- Combine aspects of alternative social spaces with permaculture and qualities of continuous horizontal and vertical landscapes.

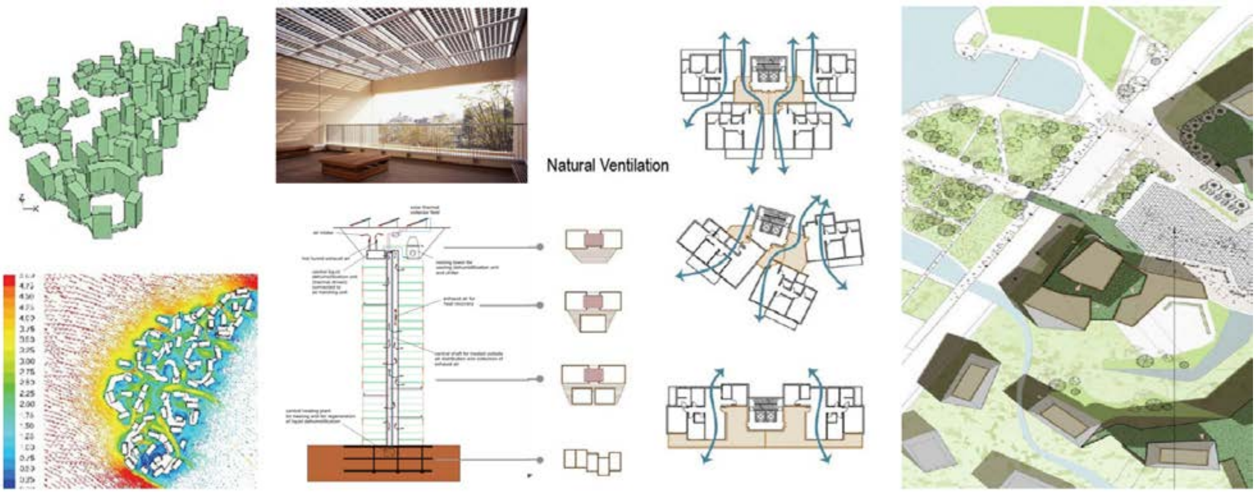

Figure 14. CFD supported design optimization, multi-scale air flow studies, urban landscaping.

The methodology of the design team was primarily focused on mirroring natural systems in the architecture. As part of the design process, the project team developed a strategy for the introduction of a system of permaculture. In the core of the project, the team designed a continuous landscape and overall site strategy to allow for a rebirth of the natural ecology (previously desecrated by monocultural shrimp farming) and the creation of an increasingly self-sufficient ecosystem. Using simulation technology, the design team modeled aspects of the ecosystem and analyzed its behavior with a focus on several design aspects like water and waste management, biodiversity and life cycle assessment. The plan of the development is derived from the organizational principle of ecological systems, enabling a growth process that provides progressive dense contemporary urban and architectural solutions and maximum flexibility for future planning initiatives.

In order to meet established planning and performance criteria, both architects and engineers focused on the utilization of enhanced natural ventilation through optimized building orientation and massing. Site density and permeable plan configurations had to allow for an 80% efficiency for the use of natural daylight. Using CFD modeling and a detailed climate analysis, an optimized form for the planning of the site was reached, fulfilling both architectural design intent and environmental performance criteria (Figure 14).

6. Conclusion

Through our practice, research, and teaching, we have developed a methodology for innovation that has the ability to transcend disciplines and design issues in the built environment. The complexities facing our urban centers today can only be addressed through an interdisciplinary working mode in order to achieve fully integrated and coordinated design solutions. While most of the work discussed in this paper deals specifically with synergies between research and teaching, a similar aggressive demand for innovation can also be applied to the construction industry, specifically in the distinct areas of project delivery, product development and process optimization.

Given significant energy consumption and carbon contributions, the construction industry is therefore an area where the effects of innovation will be most influential. As an industry primarily driven by schedules, budgets, and profit, how can we innovate in such a risk-adverse stakeholder group?

At the University of Cambridge, we are working on new digital tools that will optimize relationships between architectural design intent, structural and building environmental performance, and aspects of façade system and component manufacturability [6]. Architectural intent is hereby measured against material or assembly design constraints, and performance evaluated in a multi-objective optimization process. This work offers opportunities for combination with and extension of VDS methodologies.

Similar to our practice/research/academic tripod model, we propose that we strike a balance between process and product development as opposed to merely concentrating on project delivery. In this scenario, the market itself can also drive new relationship between product integration, supply chain optimization, and project delivery by shifting focus towards investing in innovation during times of profit surplus, in an effort to ensure continued optimized project delivery when the market is at a downturn.

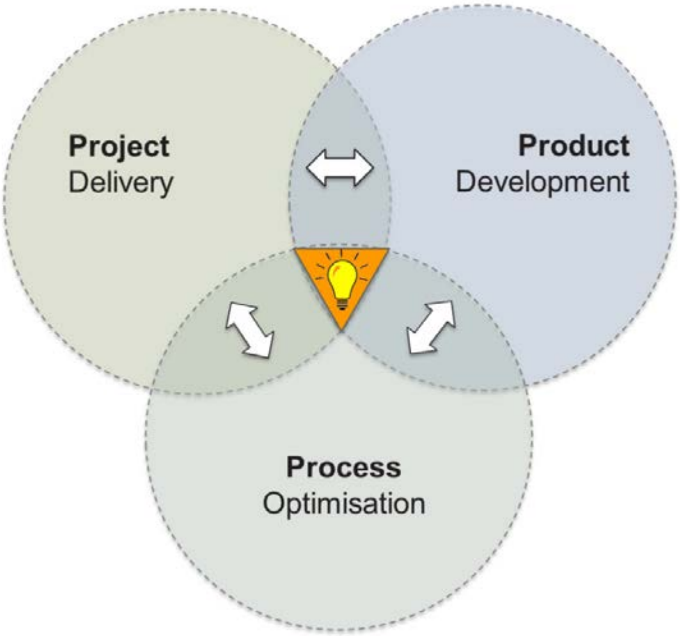

Figure 16. P+ tripod model of relationships and overlaps between key innovation areas.

Technology and Knowledge Transfer mechanisms are vital to developing a culture of innovation and process optimization. As demonstrated in our projects, applying methodologies, concepts, and products devised in the lab to the real world resulted in integrated solutions that would otherwise not have been possible in a typical business setting. Bridging this gap through advocacy and interdisciplinary outreach is therefore key to designing integrated and novel future solutions.

Important steps are being taken to streamline the design and construction process in an effort to modernize the construction industry at large. However, we need truly integrated solutions that render innovation not just as a byproduct of streamlined processes and applied lean commercial incentives—but as the heart of a synergistic approach towards inspiring, high quality architectural design supported by inventive and forward thinking building physics expertise. We therefore believe that we need to radically revisit and cultivate new collaboration models between governmental, industry and academic entities.

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