Action Plan: A Survey of Patenting and Commercializing Building Science Research within Design Programs

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This paper aggregates and analyzes data from interviews of architecture faculty across the United States who have filed patents for products, processes, and software. It discusses trends in how faculty collaborate, including to what extent students at both the undergraduate and graduate level are named as co-inventors. Analysis of the interviews reveals levels at which universities provide both financial support and training during patent filing, prototyping/testing, customer discovery, and commercialization. It also traces the types of funding and training that faculty seek, from internal university support to federal agency support, to the help that regional business incubators provide. The paper discusses the role interviewees feel that teaching can have in valuing Intellectual Property (IP), and how the structure of the tenure process can hinder the protection of IP. Finally, the paper discusses the interviewees' thoughts on how to grow a disciplinary culture that fosters both faculty and student IP creation tied to commercialization in order to significantly enhance and impact the build environment.

INTRODUCTION

A recent article in The Atlantic by Robinson Meyer entitled "The Climate Economy is About to Explode," forecasts clean energy as the leading driver to fuel future US economic growth, aided by the Biden Administration's Inflation Reduction Act. "The opportunity will be too large, the money too persuasive, the problems too intriguing… The fight against climate change is going to change more in the next four years than it has in the past 40."[1]

As we look toward the 22nd century, government agencies are investing research dollars into the green economy and infrastructure at a rate previously unseen. Funding for development of new building materials, products, processes, and software are not far behind. While innovative technologies and assemblies are ripe for development, governmental agencies are also providing funding to retrofit buildings, conceiving of new ways to employ existing materials to decarbonize and to provide resiliency as we adapt to the realities of climate change. How can design faculty be essential to this important moment in history?

This paper relates the successes and challenges of bringing patentable research to market by faculty within design programs. Interviews with faculty members discuss assumptions, expectations, and the functionality of university support. The paper also introduces how coursework can provide opportunities to engage in research, whether that is in the form of material-based investigation, or software-based analysis.

The survey for this paper identified 30 design faculty who participated in the patenting process. Of those identified, 10% completed the provisional patent process, without filing a full patent. All others received full patent protection. One third of the faculty surveyed hold doctorate degrees, and 10% were assistant professors on tenure track. Seven hold administrative positions within their respective schools or within professional organizations. The survey primarily focused upon architecture faculty. Eighteen interviews were conducted. The following text synthesizes information from those interviews.

THE QUESTIONS

The questions sought to collect data on authorship, financial support, and training. The intention was to reveal discipline-wide trends particular to design programs, while also providing opportunities to convey personal experience and narrative. Some quotes have been shortened and edited for clarity.

- Can you briefly describe your patent?
- Were you a sole inventor – or did you have co-inventors, and from what discipline did they come? Were any students designated as co-inventors?
- What financial support did the University provide? Legal fees for provisional patent application, for utility patent, support for prototyping, testing, market research/customer discovery
- Did the university put in place a gateway – only supporting some patent applications, and refusing others?
- Did your university provide you with information about support from federal agencies (DOE, USDA, HUD, NIST, DOD, etc.)? Did you receive support from an agency and at what stage of development? Was the support multi-year?

Figure 1. BioSIPs Low Life Cycle Analysis structural inventions from 100% cellulose waste fibers. Image Credit: Julee Herdt.

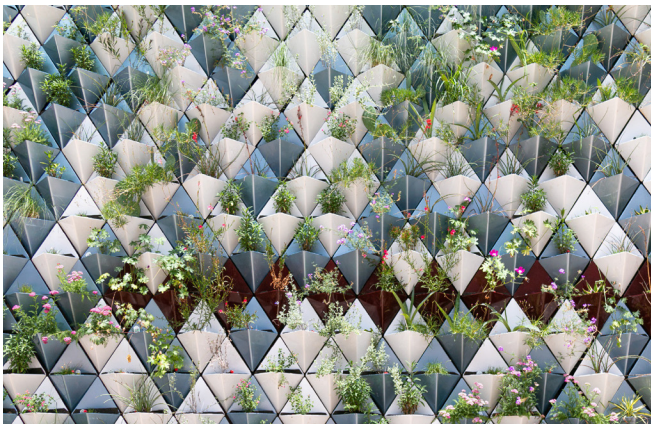

Figure 2. Modular Living Wall uses waste from the automotive industry. Image Credit: Dr. Ahmed K. Ali.

- Did your university provide training on patenting a product/process –filing, prototyping/testing, and bringing the product to market? If so what kind of training? If not – how did you learn about these processes? Do you feel the Architecture program received as much training as other programs in engineering, science, or other design fields (Industrial Design, Landscape Architecture)?
- Did you employee undergraduates or graduates as researchers during the development of your product or process? Was that support through an institute/lab, graduate assistant funding, or did you support the students out of your own funding?
- Were you encouraged to launch your own company, or to team with a manufacturer? If teaming with a manufacturer – did the University provide administrative support, or help with connecting to manufacturers? Were there state economic development funds/incentives available to encourage working with local manufacturers?
- For more recent patents, did you go through I-Corps training (NSF), IMPEL grants (DOE) or some other stepped program that provides financial support for small business entrepreneurs?
- What things do you think need to happen to encourage architecture faculty to seek patents in the building sciences?
- What pertinent question hasn't been asked? Or also what other things do you wish to relate?
- Finally – Is your program STEM designated, and if so, do you see any influence of that designation on your program, or research within the program, and have there been conversations about how that designation might enhance research?

THE PATENTS AND THEIR INVENTORS

The interviewed faculty described a range of patented products and processes including ceramic tile, SIPS panels, both wood and cellulose engineered structural systems, concrete printed housing, a double façade skin, a living wall, concrete block, roofing made of discarded water bottles, a home health station, a continuously variable bicycle transmisssion, expeditionary shelters for the Army, methods for producing folded fiberglass panels and a method for producing bamboo structural panels. Computer applications ranged from shape grammar selecting software, to a biophysical response data analysis application that evaluates a building's health benefits. Based on the survey group, 75% of the patents protected IP for products and manufacturing processes, while the remainder of the patents focused upon software applications.

This paper interviewed design faculty who acted as lead inventor, rather than being a part of a team led by engineers. The reasoning behind this was to better understand the experience of design faculty as they engaged with the patent process. Many of the inventors collaborated with faculty in engineering, and materials science. Inventors also worked closely with industry partners, and in some cases with federal agency and federal laboratory employees. Nearly every inventor paid undergraduate or graduate students as researchers. 40% named students as co-inventors, with half of those being undergraduate students. As universities increase emphasis on the value of undergraduate research, these findings highlight an alignment with the willingness to introduce students to research early in their academic careers with the fact that architecture as a discipline primarily awards baccalaureate and master's degrees.

> I recently began collaborating with a researcher at the National Renewable Energy Laboratory. We are using the bioresin he developed with the cellulose based structural core from BioSIPS to create extremely low carbon footprint structural members. The Small Business Innovation Research program through the US Army is funding this research.
>
> —Julee Herdt, University of Colorado Denver, Inventor BioSIPS (fig 1)[2]

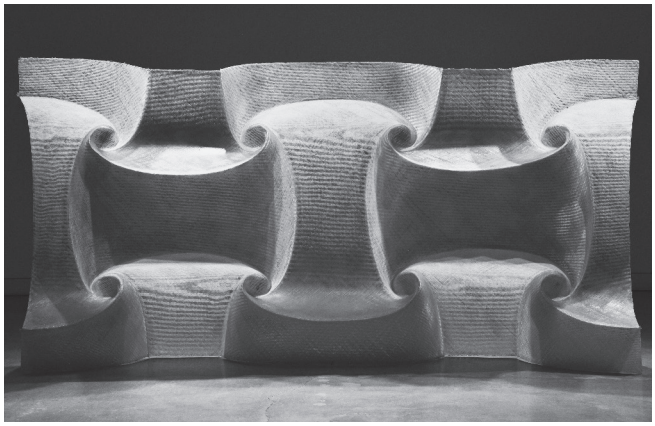

Figure 3. Folded fiberglass pane designed by Dr. Joseph Choma and fabricated using his patented method.Image Credit: Dr. Joseph Choma.

Figure 4. CS Plasma Tile, Black Tile House, Rui Pereira Architects, inventor Jose Pinto Duarte with Luisa Caldas, Daniel Mateus, Joana Peres, and Raquel Ribeiro. Image Credit: CS Coelho da Silva.

UNIVERSITY SUPPORT

Patents protect novel, non-obvious, and useful inventions, which are a type of intellectual property (IP). Faculty begin the patenting process by filing an Intellectual Property Disclosure Form with the university, and the university then engages legal counsel to file a provisional patent application. At that time of completing the disclosure form, ownership of the IP is transferred from the faculty member to the university. To provide international patent protection the IP must not be publicly disclosed through communication prior to filing the provisional patent application. For United States protection alone, the IP may be publicly disclosed up to a year to the day prior to filing the provisional patent application. Within a year to the day of filing the provisional patent application, a utility patent, design patent, or software patent must be filed in order to protect the invention (also called a non-provisional patent). After a year to the day of filing the provisional patent application, the provisional patent protection lapses, and the original protection date can no longer be enforced. If a patent is infringed upon, the university provides legal protection. Filing a copyright provides the designer with more limited protection than a patent.

> The university filed my provisional patent application but did not notify me when the filing was ready to lapse. I did not really understand how to move the product to production and so when the manufacturers that I contacted did not show initial interest I did not further pursue patenting the product.
>
> —Geoff Gjertson, The University of Louisiana at Lafayette, Inventor Cajun Block[3]

The university's innovation and commercialization office typically files the patent application. In some cases this office is within the research arm of the university, in other cases it is a separate research institute or limited liability corporation. The financial structure of this office may result in different expectations for interacting with the faculty member during the patenting and commercializing of a product. Once a patent is issued, a patent license provides a company with the right to make, sell, or use the invention, and typically the company pays royalties or licensing fees for that right to the university. The university then shares a portion of those fees with the inventor. Interviewees revealed that universities will typically file provisional patent applications but may gate keep at the point of non-provisional filing. This may be due to evaluation for prospective commercialization. Key to this is whether faculty have completed customer discovery, collected proforma data, and/or identified industry partners, while also further demonstrating the novel, non-obvious, and useful characteristics of the invention. Faculty also report that in some cases communication about non-provisional filing is delayed, and if the university does not support such filing, the faculty member's prospects of filing individually is hampered by closeness to the end of the one year provisional protection date, endangering continuous protection of the invention.

> My first provisional was a mass timber non-glued technology called Interlocking Cross Laminated Timber. It was supported by a couple of USDA Forest Products Laboratory grants. The second was an at-home-health-care cart that contained all of the necessary equipment for at-home -health-care anticipating the transition to at-home-health nationally. This was supported by an internal grant from the university. The University of Utah covered the disclosure process and provisional patent filing, but they were not willing to go beyond that as they did not see a market opportunity imminent.
>
> —Ryan E Smith, University of Arizona, MOD X Consultant[4]

Designers combine elements, processes and systems into a new way of thinking about a product. If the legal review determines that the combination does not sufficiently meet the novel,

non-obvious, and useful standard for a patent, there are still ways in which the idea can be protected. The protection may not be for as long of a duration, or as complete, but it can still give the author a measure of security while developing and commercializing the product.

> Even if the reviewers determine that an invention will not be awarded a utility patent, it is important that the IP is still valued and protected during the product development and commercialization process – a provisional or design patent can be the right answer.
>
> —Dr. Ahmed K. Ali, Texas A & M University, Inventor Living Wall (fig 2)[5]

SUPPORT OUTSIDE OF ACADEMIA: FEDERAL AGENCY, INDUSTRY, AND EXTERNAL FUNDING SOURCES

Interviewees reported a wide range of funding sources that they accessed during the stages of developing their inventions from prototyping to customer discovery, to identification of industry partners, to commercialization. Interviewees reported receiving grants for equipment through the National Science Foundation Established Program to Stimulate Competitive Research (EPSCoR), undergraduate research support through the National Institutes of Health, product development through a US Army sponsored Small Business Innovation Research (SBIR) grant, aid in customer discovery through a regional Innovation Corps (I-Corps™) program, and small initial grants through the US Department of Agriculture Forest Products Division. In two cases, inventions were conceived during the design of Solar Decathlon Houses, funded by the Department of Energy.

> The DOE sponsored our participation in the [Solar Decathlon] competition and provided $50,000 to us as a kind of a seed grant to kick-start our project. So, to be clear, this DOE funding was not aimed at directly supporting the development of our patentable technology. Rather, our conceptualization and development of the building framing system came later, as the process unfolded.
>
> —Dustin Albright, Clemson University, Co-inventor CNC Milled Building Framing System[6]

The particularities of agency funded programs sometimes come with complications for faculty. SBIR, which funds support to commercialize research, appears attractive to the development of products and processes, but SBIR requires the principal investigator must be primarily employed by a small business. This is in conflict with full time employment at a university as a faculty member. This means the faculty member must collaborate with a non-faculty employee hired to act as a principal investigator. For some interviewees juggling the establishment of a small business with the development of a product proved too far outside the faculty member's wheelhouse to merit pursuing funding through this type of source.

Grants such as the American Institute of Architects Upjohn award, the Architecture Research Centers Consortium awards, and the AIA New York research awards provide support for proof of concept. While prestigious, interviewees mentioned these relatively small grants quickly dwindle in the face of indirect costs deducted by the university. Publicizing the outcome of the grant may also put protection of the IP in jeopardy through disclosure.

Another area of consideration is the process of converting the IP into a product or process that is available to the public. The patent and commercialization process typically assumes a for profit model. However, standard commercialization may not always be the correct path, such as in cases where the inventor wishes to share the information for the greater good. For example one interviewee was interested in providing locally sourced building materials in developing nations. This led to consideration of a different business model, establishing a not-for-profit company, and seeking grant money from foundations or not for profit development agencies.

> I received a $1.5 million grant from USAID to work with a Filipino partner to design a bamboo structural panel. Virginia Tech wanted me to file a US Patent to provide protection against commercialization by another company in the United States. I conceived of this whole process differently. I favored a creative commons licensing agreement, where small companies in places like the Philippines could invest and investigate bamboo construction. The real value is letting collaborators around the world use the system to create better housing conditions and better environmental conditions. My main goal was to distribute the system.
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> — Jonas Hauptman, Virginia Tech University, Inventor Smart Cross Bamboo[7]

INTELLECTUAL PROPERTY WITHIN THE DISCIPLINE'S CURRICULAR AND ADMINISTRATIVE STRUCTURE

The National Architectural Accrediting Board (NAAB) conditions for accreditation ask programs to demonstrate community engagement as a shared value, and research and innovation as a program criterion. If local industry is perceived as a partner in the pursuit of IP in classes, the associated curriculum can be seen not only as research, but also as community engagement.

> In my courses, I ask students to develop innovative products tailored to the industrial partners I have on board to fund the studio. Sometimes we give the manufacturer the IP when the partner financially supports the studio. Facilitating these studios can cost up to $25,000. After we provide the company with the basic design idea, the company works to make it reproducible. Working with local firms fulfills the outreach mission of the university; it creates local employment and good will. Much of the work we do is published in science magazines targeted to the public – like Popular Science magazine – in addition to scientific

> journals and conferences. This increases awareness of our work and brings us more industry partners.
>
> — Dr. Jose Pinto Duarte, Penn State University, Inventor Customized 3D Printed Concrete Housing and Ceramic Tiles (fig 4)[8]

When architecture programs renovate, they might also consider how the spaces of teaching can be developed to physically include the pursuit of research. In particular industry partnerships can result in changes to the traditional design of studio spaces, allowing students to directly test their ideas.

> We have created three new research labs, that are also classrooms/studios. Around the perimeter are still desks, but the space itself, because of the equipment, has become a different instrument with which to learn. We are literally embedding research into our physical infrastructure by transforming the space we have.
>
> — Dr. Joseph Choma, Florida Atlantic University, Inventor Foldable Fiberglass Sheets (fig 3)[9]

While IP is seen as a key way to engage students in research, valuation of IP must also be considered as students complete advanced degrees, as they then transition into the profession of academia, and, as faculty, progress through the tenure and promotion process. As students prepare PhD dissertations or transition from being a graduate student to taking a faculty position, there is significant pressure to publish research, either for completion of a dissertation, or to begin the tenure and promotion process. For dissertation, some universities have made structural changes to accommodate obstacles between public disclosure and IP protection.

> Our University makes it very simple for disclosure, and can embargo dissertations and whatnot long enough for the patent to be awarded.
>
> — Dr. Lee Fithian, University of Oklahoma, Inventor Apparatus and Method for Improving Air Quality in Street Canyons, Double Facade System[10]

Transition from one institution to another adds complication as often the initial IP is owned by the school the student attended. As the student transitions to a faculty position, they must negotiate working with the original institution who owns the IP with continuation of their research with the new institution. IP transition between schools is often ad hoc and completed by an early career academic with little or no training in the process.

> RPI was very communicative about owning the intellectual property of their students. Since RPI may have held some claim to the work [that I did as a graduate student], and since more than a year passed after the publication of my Masters' thesis, the patent with Cal Poly only covers new developments in the project. This decision was in part because of the complexity of developing the work at two institutions, and also because the idea had been in the public domain for too long.
>
> — Carmen Trudell, Caly Poly, Inventor Coupler for Passively Collecting Particulates in a Concrete Masonry Unit[11]

As young faculty build a tenure and promotion package, many interviewees mentioned that the requirement to publish negatively impacted protection of IP. This was both due to a lack of training for the individuals and training of program administration on how to value and protect IP. By publishing, their research was released into the public realm, and a lack of understanding of calendar implications resulted in paperwork for protection not being completed in the required one-year period. Program investment in commercializing the IP is an additional missed opportunity.

> Architecture programs need to encourage faculty in order to respect the IP that they are producing. These programs need to invest in architectural faculty to take the IP to market, to make it into an economically viable translation into products and services. We traditionally think the ACSA conference paper, or the JAE/TAD article, is our sandbox. Expanding consideration of IP disclosure as counting, like the publication of a journal article for evaluation during tenure and promotion, would be a positive step in the right direction..
>
> — Dr. Ganapathy Mahalingam, North Dakota State University, Inventor Biometric Data Collection and Analysis System[12]

Interviewees also mentioned that the traditional way of teaching Architecture through design studio, in conjunction with lecture and laboratory-based technology courses provides another impediment. Graduate faculty in science and engineering may carry a workload of six to nine credits per year and advise PHD students. In comparison, Architecture faculty typically carry a courseload of eighteen credits, which includes twelve hours of studio contact time per week. The sheer time commitment for these courses makes it difficult to participate in patenting and commercializing research.

Finally, many programs have recently sought STEM designation administratively, placing value on STEM's potentiality within the discipline of architecture by adopting the Department of Homeland Security CIP CODE 04.0902 (Architectural and Building Sciences/Technology). This allows for international students to participate in a 24-month STEM Optional Training Program after graduation. In discussing the designation, many of the interviewees stated that their Architecture programs had received STEM designation. However most interviewees had not

yet witnessed conversations about how the designation might change curriculum or recruitment, even though this designation is poised to increase both research and funding opportunities. For one interviewee, a mistaken assumption about STEM designation was nearly detrimental.

> Because of some confusion with the specifics of the STEM designation for my PHD program I was not given the option of OPT, even though I entered the program believing it was STEM designated. The PHD program included history, criticism, computer science, design health, and simulation all together as a single PHD program. What we discovered was that as long as there was one group that is not STEM within the cohort, then the entire program was not STEM. We discovered this one month before graduation. Luckily, I had already been offered employment at the University of Kansas.
>
> —Dr. Kurt Hong, The University of Kansas, Co-Inventor The Shape Machine[13]

FOSTERING THE VALUE OF INTELLECTUAL PROPERTY WITHIN OUR DISCIPLINARY CULTURE

For designers the dance between ideas and solutions seems obvious, because this kind of play at connecting one piece to the next is part and parcel to a designer's training. Too often designers do not consider the design process as the production of IP.

> I was invited by the American Composites Manufacturers Association to compete in a challenge asking for architects from academia to find new applications for fiberglass. They said you cut up the material and put it in the mold and I thought this is a beautiful textile, it's such a shame we are chopping it up. Maybe we should think of it as a surface logic, and then I thought about shirt collars and how we starch them, and then I thought about fabric hinges sometimes used in furniture applications and then I thought what if I use masking tape to only selectively coat the fabric, and that would allow it to fold. When I presented the idea, it seemed so trivial. The only reason why it wasn't trivial was that no one had ever done it before.
>
> — Dr. Joseph Choma, Florida Atlantic University, Inventor Foldable Fiberglass Sheets[14]

While the discipline favors imaginative problem solving, Architecture pedagogy also advocates for singular tailored solutions for the individual client and specific design problem. Architecture education prioritizes the singular masterpiece. Unfortunately, singularity is in direct opposition to replicability and commercialization of products.

> Architects too often build one offs, and one offs do not fit into the culture of manufacturing.
>
> — Jason Van Nest, New York Institute of Technology, Inventor Roofing Made From Discarded Water Bottles[15]

Institutional valuation of IP within an Architecture program can depend upon where the program is located within the university's organizational structure, and whether faculty and administration are encouraged to embrace ways of thinking aligned with disciplines outside of Architecture.

> The valuation of Intellectual Property depends greatly on if the Architecture degree is located within an engineering school where there is likely to be more support and training. If the department is in a College of Liberal Arts, or College of Arts – a culture of IP protection and commercialization may not exist.
>
> — Jason Van Nest, New York Institute of Technology, Inventor Roofing Made from Discarded Water Bottles[16]

While universities have promoted trans-disciplinary and inter-disciplinary research for decades, the training that faculty in these other fields receive is not often emphasized as important within the discipline of Architecture.

> To be successful inventors, Architecture faculty have to think about how faculty train in the sciences and engineering, how to write and think in different ways – like a business person, like a lawyer. In order to make a difference, to make an impact, an inventor has to commercialize, and that means thinking in terms of money, in terms of proformas.
>
> —Julee Herdt, University of Colorado Denver, Inventor BioSIPS[17]

To create an environment that is more open to IP, Architecture faculty need to be made aware of what is patentable. This awareness can be increased through campus intellectual property offices providing information sessions and training to design faculty, or through increased awareness of research initiatives through articles and awards for research and development.

> I think that college and university research offices should work with their respective schools of Architecture and, among other things, specifically highlight the topic of patentable technologies and processes. It has not been for all that long that Schools of Architecture have been seen in the academic community as potential centers for capital R "Research." That is changing.
>
> — Dustin Albright, Clemson University, Co-inventor CNC Milled Building Framing System[18]
>
> In many ways, inventions are similar to architecture design, defining problems, and solving them with parameters, benchmarks, objectives. Maybe architecture magazines

should institute R&D awards or other ways to increase awareness of patented or patentable intellectual property.

— David Rockwood, University of Hawaii, Inventor Continuously Variable Bicycle Transmission[19]

CONCLUSION

This paper serves as a mere introduction to a broader discussion on the valuation and commercialization of IP by faculty and administration within the discipline of Architecture. Garrett Ricciardi, who taught a course entitled "Pending: Architectural Patent Office" as a technology seminar at the University of California Los Angeles during COVID, points out that the history of patenting goes back to Brunelleschi, and that architects and artists like Norman Foster, Buckminster Fuller, Richard Neutra, Stephen Holl, and James Carpenter have protected their IP through patents. Engaging in filing patents and teaching students the framework of patenting preserves a long history of protecting IP within the discipline. It also provides alternative ways to engage students in research, writing, drawing, and the business of architecture through methods that favor objectivity over subjectivity.

Designing through the lens of patenting provides objective criteria with which to evaluate a project. It is clear how to assess what is specifically different from all the other products that solve the specific problem. Both through drawing and writing, it addresses representation from lenses that differ from contemporary pedagogy. And it engages in entrepreneurism in a way that can easily be discussed.

— Garrett Ricciardi, University of California Los Angeles[20]

As the discipline engages in research that has IP significance, faculty, administrators, and the universities themselves will need to consider how best to build upon the impact of this research. Certainly the financial impact of encouraging the protection of IP and invention will be undeniable when it begins to change the financial underpinnings of our discipline's programs.

When your research earns millions of dollars in grants, and the associated overhead begins supporting your college in ways that were previously unimaginable, suddenly your research becomes much more recognized and impactful - not only within our discipline but also as it supports faculty development in other fields within the college.

— Peter Wiederspahn, Northeastern University, Inventor Expeditionary Shelter[21]

At the same time, programs must recognize that the discipline of Architecture has the potential to expand its role within the economy as a leader in the development IP to meet the challenges of climate change and resilience.

The patents are the easy part. The goal of research should be impact, not grants or patents or papers, though each can be useful if they are understood as steppingstones to impact.

—Francisco Gomes, University of Texas at Austin, Inventor Masonry Wall System[22]

Governmental agencies in the United States have committed 350 billion dollars to mitigate climate change by altering our infrastructure and built environment. Significant funding has already commenced, and it will complete within less than a decade. As design faculty, it is important to understand where our discipline stands currently, and what obstacles need to be overcome in order to efficiently organize our efforts to be leaders in applied research at this important moment in history for building science. This paper provides a survey of where we stand at this moment.

ENDNOTES

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