Creating Our Own Ladder to Climb: Architects Setting Policy Using the Climate Stabilization Triangle Method

Courtney Crosson [1]

[1]University of Arizona, Tucson, Arizona

ABSTRACT: This paper addresses the pedagogical process of teaching architects to operate within a system of limited resources – by having them design the regulatory game to manage those resources. In 2015, the president of the University of Arizona (UA) signed a commitment to reach carbon neutrality by 2050. In 2016, an upper-level architecture studio was planned in partnership with university administration to create a roadmap for the campus to achieve this neutrality commitment. The studio pedagogy was structured using the climate stabilization triangle method, originally pioneered by scientists Stephen Pacala and Robert Socolow, co-directors of the Princeton's Climate Mitigation Initiative. Pacala and Socolow assert that rather than advancements from the lab bench or computational model, forthcoming answers to global warming will be provided by those that coordinate the implementation of a portfolio of existing solutions (Pacala 2004). Students created a climate stabilization triangle for the 2050 campus by projecting the future escalation of campus scope 1-3 carbon production and then coordinated existing mitigation strategies to reach a zero target. Each implementation given by the students had a stated funding strategy, policy outcome, and corresponding physical outcome for the campus. The UA is currently integrating the work as a chapter in the campus master plan for 2018. The paper argues that by designing their own ladder of regulations, students learn to dissect why policy exists, connect physical outcomes with policy mandates, and understand their work as an architect within the complexity of actors and objectives impacting global warming. Architects can play a central role in the growing imperative of climate planning if methodologically trained with the current research methods and analytical tools to address this challenge.

KEYWORDS: net zero, climate stabilization triangle, wedge diagram, carbon neutrality, campus master plan

INTRODUCTION

> Humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century. Every element in this portfolio has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale. Although no element is a credible candidate for doing the entire job (or even half the job) by itself, the portfolio as a whole is large enough that not every element has to be used.
>
> : evolutionary biologist S. Pacala and physicist R. Socolow, in Science in 2004

In 2004, scientists Stephen Pacala and Robert Socolow delivered a hopeful message: society is in a position to solve the problem of climate change for the next half century, now. Rather than new research and development, the problem can be addressed for a 2050 target through the coordination of a portfolio of existing solutions. Pacala and Socolow devised the stabilization triangle method to view projected carbon increases alongside the stepped mitigation strategies to achieve a desired level of future mitigation (Pacala 2004). This tool is used to sequence and understand the impact of a portfolio of solutions for a given carbon emitter.

In 2015, the president of the University of Arizona (UA) signed a commitment to reach carbon neutral by 2050 under the American College and University Presidents' Climate Commitment (ACUPCC). Upon taking this pledge, the UA had created a climate stabilization triangle projecting future campus scope 1, 2, and 3 carbon emissions and a 2050 zero target. However, the most important piece of the stabilization triangle was missing: the coordinated portfolio of existing solutions. In 2016, university administration and a professor at the UA School of Architecture partnered to form an upper-level architecture studio course to create a roadmap for the campus to achieve its neutrality commitment and an additional, unique target of water neutrality. Fundamentally, architecture pedagogy trains students to coordinate a distinct set of resources to achieve a maximum effect. Pacala and Socolow outlined a solution to climate change where these type of coordination and optimization skills are required, rather than the skills of climate scientist or policy analysist.

This paper outlines how future architects can use their unique, fundamental skills to address a warming climate. This paper focuses on the stabilization triangle method to solve for carbon and water neutrality for the UA campus by 2050. The paper starts with a discussion of the ACUPCC and its implementation challenges. Then, carbon and water neutrality are defined. Next, the stabilization triangle method is outlined using the case study of a UA architecture studio course. The paper concludes with a discussion of the opportunities, challenges, and potential impact of the stabilization triangle method on architecture pedagogy and ACUPCC signatory campuses. The paper argues that architecture students learn to orchestrate physical change through policy mandates and incentives and ACUPCC campuses are given actionable plans to bridge from goals to tangible implementation.

1.0 CAMPUS MASTER PLANNING AND ACUPCC SIGNATORIES

Campus master plans, traditionally led by teams of architects, have increasingly changed from an exercise in land planning and vision rendering to a focus on strategic resource allocation and management. For example, Rice University's recent 2014 Integrated Campus Plan is undertook this shift. The recent Kieran Timberlake plan aimed to minimize energy use, efficiently deliver resources, and ameliorate flooding risk (Harris 2017). These goals bear stark contrast to Michael Grave's 1990 Rice University master plan that choreographs building placement and warmly renders visions of stylistic unity (Coulson 2015).
In 2006, in line with this shift in campus planning and growing concerns over climate change, the ACUPCC was launched as a collective effort by higher education institutions to pursue carbon neutrality in campus operations and master plans. To date, the commitment has been signed by over 700 colleges and universities within all 50 states (ACUPCC 2017, Dyer 2017). Signatories develop an implementation plan with carbon emission targets and timetables, integrate sustainability and climate change into the curriculum, and make their plans and greenhouse gas inventories publicly available. Between 2007 and 2012, ACUPCC institutions reduced GHG emissions 25% on average across the network (ACUPCC 2012). Although, the commitment has had a significant impact on many campuses, still over a third of signatories struggle to move from goal setting to implementation of policies and initiatives to meet targets (Dyer 2017). Currently, only 61% of the signatories that have submitted two or more greenhouse gas (GHG) inventories have reported a decrease in carbon emissions (ACUPCC 2017). This paper outlines how architectural pedagogy can support ACUPCC campus signatories, like the UA, by creating a pathway to successful reduction and goal attainment with the stabilization triangle method for carbon and water neutrality.

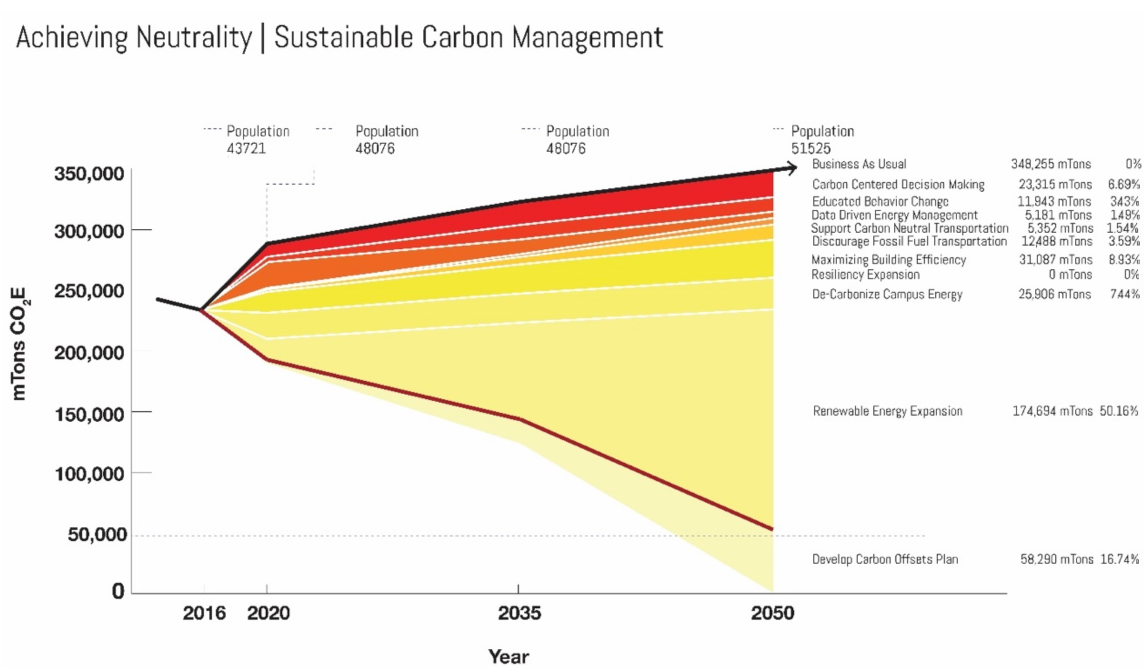

Figure 1: The stabilization triangle created for UA 2050 carbon neutrality. Source: (Author and UA ARC451b 2016)

2.0 DEFINING NEUTRALITY AND UNDERSTADNING LOCAL SPECIFICITY

There are a range of definitions of carbon neutrality based on the inclusion of indirect and transportation emissions. The definition for water neutrality is even murkier as a nascent concept. The functioning definition for neutrality used by this paper are stated below.

2.1. Carbon Neutrality and the Local Campus Reality

Carbon neutrality is defined in this paper as eliminating or offsetting the amount of carbon produced within a given site such that there is a zero or neutral annual effect (US Department of Energy 2015). Carbon emission sources are broken into Scope 1 (direct sources), Scope 2 (indirect sources), and Scope 3 (transportation related sources). Each ACUPCC campus working toward neutrality faces unique challenges based on current energy demand profile (e.g. heating and cooling loads), current energy generation infrastructure (e.g. direct or indirect sources, gas or electric generation and distribution), and transportation needs (e.g. commuter campus or required onsite living). To achieve the ACUPCC goal of carbon neutrality the decarbonization of a campus's energy infrastructure is largely required. Current central plant infrastructure must change to electrical energy supply rather than one that is fossil fuels based.

The UA has three central plants and operates on a cogeneration system (COGEN) and steam supplied heating. The efficient COGEN system of capturing and repurposing waste heat to further provide energy to the campus unfortunately involves carbon emitting fuel sources. Additionally, the steam system is powered by natural gas generators linked to an extensive pipe distribution system. The UA also hosts a large solar array on its property on the outskirts of Tucson through a power-purchasing agreement (PPA). The 2015 carbon inventory for UA was 80,268 metric tons of CO2e for scope 1 (34.5%), 92,837 metric tons of CO2e for scope 2 (39.9%), and 59,392 metric tons of CO2e for scope 3 (25.6%) (STARS 2017).

2.2. Water Neutrality and Local the Campus Reality

Water neutrality is defined in this paper as maintaining an annual sustainable water supply such that no imported water is needed. On a water neutral campus, the amount of water that is used is locally recharged and one hundred percent of historic storm water flow is mitigated within the site boundary for ecological benefit (International Living Futures Institute 2018). The particular challenges of achieving campus water neutrality vary greatly based on the local precipitation profile (e.g. frequency and intensity of rain), the probability of extreme events (e.g. floods and drought), local hydrogeology (e.g. ground water availability), and local permeability (e.g. available permeable land cover and soil absorption capacities).

Currently, the UA receives over half of its potable water from on campus wells (STARS 2017). Although in a desert location, the UA is at the convergence of water sheds from the surrounding four mountain ranges: Rincon Mountains, Santa Catalina Mountains, Tucson Mountains, and Santa Rita Mountains. Additionally, the Sonoran Desert climate is characterized by two significant annual rain events. The winter rains come off the Pacific and reach Tucson during the months of December and January. The summer monsoon rains come off the Sea of Cortez and arrive during the months of July, August, and September. The monsoon rains provide a deluge that fertilizes desert plants and creates significant storm water flooding issues throughout the city, while the dry desert conditions the remainder of the year raise drought concerns. The 2010 water sources for the UA were 75 million gallons reclaimed water (12.8%), 250 million gallons municipal water of which roughly a third is imported (42.7%), and 260 million gallons campus wells (44.4%) (STARS 2017).

3.0 METHODS

To achieve campus carbon and water neutrality by 2050, the stabilization triangle was used as a structuring method. This section outlines the case study of an upper level, vertically integrated architecture studio at UA comprised of six fifth-year Bachelor of Architecture students, four second-year Master of Architecture students, and one professor. Four stages comprised the semester-long formulation of a neutrality pathway with the stabilization triangle: (1) Baseline Calculation (top line), (2) Goal Setting (bottom line), (3) Sequencing (vertical line), and (4) Achievement (Figure 1 & 2).

Over the course of the semester, students were charged to deliver four components to illustrate the achievement of the 2020, 2035, and, ultimate, 2050 goals: (1) carbon and water wedge diagrams illustrating the sequenced reductions based on their prescribed implementations (see Figures 1 and 2), (2) a detailed timeline of implementation (see Figure 4), (3) a "play book" sequenced from short term to long term implementations (see Figures 5, 6,and 7), and (4) an exploded axonometric drawings of resulting carbon and water neutral system designs. The resulting product was the design of a system of interrelated policies sequenced temporally and spatially delivered as thirty carbon and thirty water operations presented to UA administrators in the form of a 240 page electronic and physical book.[i]

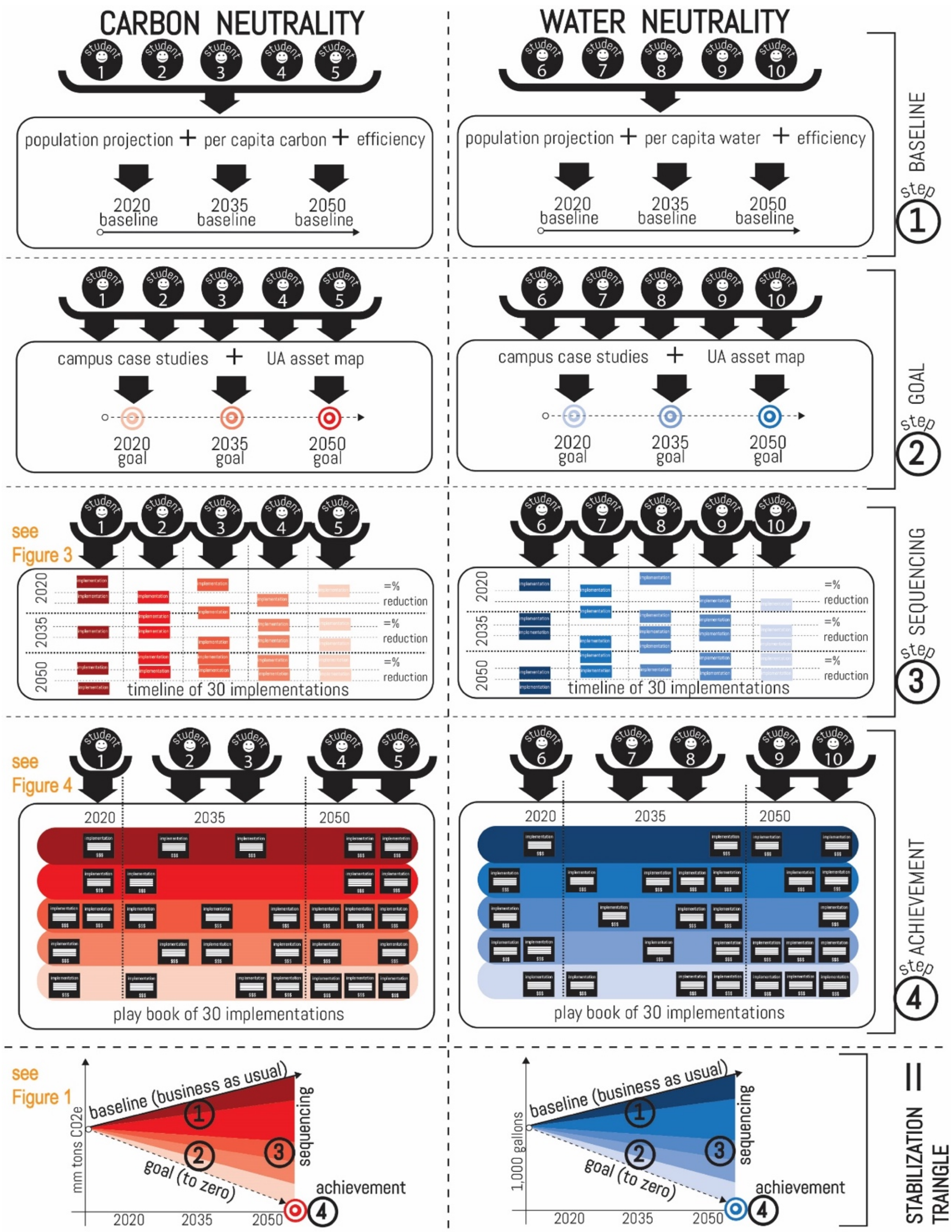

Figure 2: The stabilization triangle method used in an upper level architecture studio course. Source: (Author 2018)

3.1. Baseline Calculation: Setting the Business as Usual Short, Mid, and Long Term Case

First, a baseline for 2015 and a set of baseline projections for the short (2020), mid (2035), and long term (2050) carbon emissions and water use were constructed. The baseline formed the top line of the stabilization triangle (Figure 1 & 2).

1. Current Carbon and Water Data Analysis: The first step in this process was to establish a baseline for 2015. *S*tudents worked with campus administrators and facilities managers to analyze current campus carbon and water data and establish a current status of annual emissions and use. Data was provided through the self-reporting score card interface from the Association for the Advancement of Sustainability in Higher Education (AASHE) Sustainability Tracking, Assessment, and Rating System (STARS) (STARS 2017).
2. Creation of Per Capita Carbon and Water Annual Demand: This analyzed data was then divided by the total 2015 population of the UA to derive a per capita annual consumption for carbon and water. Population data was provided by the Arizona Board of Regents (ABOR) Annual Report (Arizona Board of Regents 2015).
3. Population Projections: UA campus population projections for 2020, 2035, and 2050 were extracted from the ABOR Strategic Plan for state university campuses (Arizona Board of Regents 2015).
4. Carbon and Water Projections for Short, Mid, and Long Term: The future carbon emissions and water use were calculated by multiplying the per capita carbon emission and per capita water use by the projected population for 2020, 2035, and 2050.
5. Discount for Future Efficiency: A discount number for future efficiency was created by comparing 2015 and 2010 per capita data and national projections for future energy and water efficiency. This constructed discount number was then applied to create the final 2020, 2035, and 2050 baseline numbers.

3.2. Goal Setting: Identifying Opportunities

Next, case studies of high performing sustainable campuses and an asset map of existing UA sustainability features were completed. From this research, a portfolio of thirty carbon and thirty water existing solutions were identified to meet neutrality goals. These short, mid, and long term goals formed the bottom line of the stabilization triangle, culminating in the final zero target on the x and y axis in 2050 (Figure 1 & 2).

6. Case Study of High Performing Sustainable Campuses: Students researched ten campuses that had been nationally identified through AASHE as achieving ambitious carbon and water goals. Student inspected the incremental, phased milestones each of these campuses had set.
7. UA Campus Sustainability Asset Map: Students broken into groups and identified current UA campus assets in four categories: Infrastructure and Resilience (renewables, active systems, indoor water management), Connections and Logistics (public transportation, bicycle and pedestrian, and waste management), Nature and Health (green spaces, outdoor water management, health and wellbeing), and Culture and Place (green buildings and education). These four categories comprised the possible areas that could be expanded for increased success at UA.
8. Identify Portfolio of Solutions: From the best practice case studies and identified campus assets, students identified a portfolio of thirty carbon and thirty water existing solutions to be employed to reach the carbon and water neutrality goals at UA. Students codified five overarching principles to guide the selection of the portfolio of solutions: (1) Spirited Optimism, (2) Principled and Practical Action, (3) Transformative Thinking, (4) Responsible Risk Taking, and (5) Organizational Effectiveness.
9. Set Milestone Goals: Based on the research of other campuses' incremental goals and the selected portfolio of solutions for UA, students set 2020, 2035, and 2050 goals. These targets formed the bottom line of the stabilization triangle (Figure 1 & 2).

3.3. Sequencing: Spatial and Temporal Dependencies

The thirty carbon and thirty water implementations were then temporally sequenced across the short (2020), mid (2035), and long term (2050) targets. The stabilization triangle was used to choreograph how each of these implementations contributed to the set milestone targets toward the final neutrality end. The carbon and water implementations were also spatially coordinated. This portfolio of sequenced solutions formed the final, vertical line of the stabilization triangle, along the y axis (Figure 1 & 2).

10. Assign Implementation Groups: Students were each assigned a set from the thirty carbon and thirty water implementations in the portfolio and asked to identify steps toward action.
11. Coordination of Temporal Sequence of Implementations within Carbon and Water: Students then were broken into pairs and tasked with either short, mid, or long term period within either carbon or

water, for a total of six groups. The identified implementation steps from step 10 were then organized by each of these six groups into a timeline (see Figure 3).

12. Coordination of Spatial Sequence of Implementations between Carbon and Water: Students in carbon and water short, mid, and long term groups met to coordinate across campus, as practical considerations for implementations overlapped between carbon and water (e.g. retrofitting, carbon and water tax)and reductions has co-effects (i.e. the energy-water nexus).

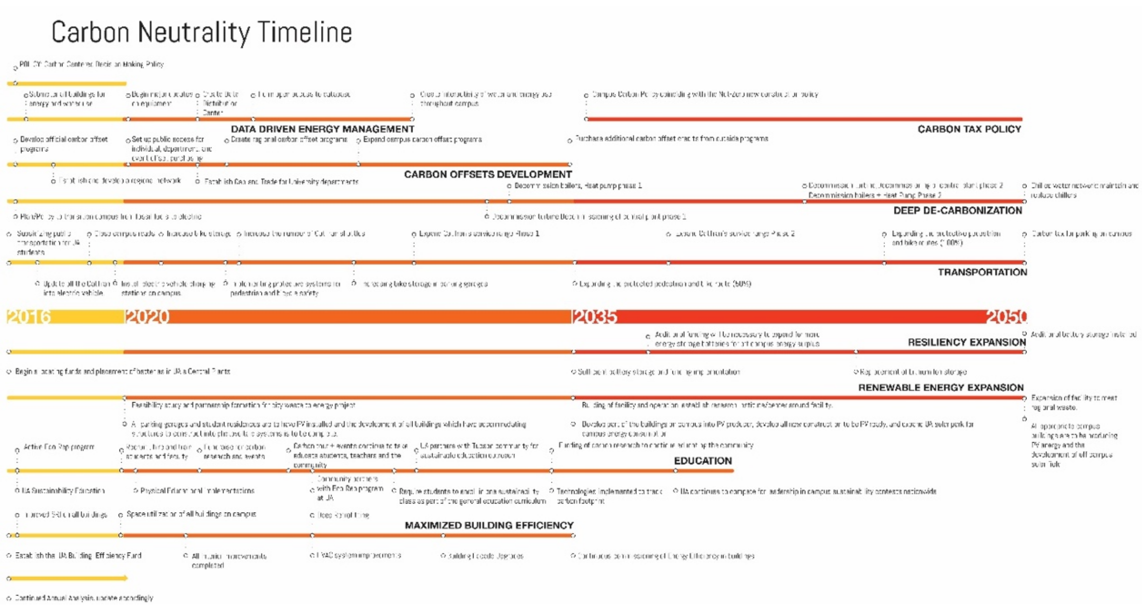

Figure 3: The coordinated implementation timeline for UA 2050 carbon neutrality. Source: (Author and UA ARC451b 2016)

3.4. Achievement: Dissemination of the Playbook and Stabilization Triangle

Finally, students put their work together into a book and disseminated it through presentations to the UA administration and broader public. The achievement was proven by meeting the target on the stabilization triangle (see Figure 2).

13. Details of the Existing Solutions Portfolio: Students created a series of pages for each of the thirty carbon and thirty water implementations into a playbook. Each implementation had a policy and physical outcome, a suggested funding source, a list of necessary stakeholders from the campus and community, and a set of linked implementations (see Figure 4).
14. Stabilization Triangle Finalization: These final implementations were then tagged with a projected decrease in either carbon or water from the baseline numbers. These numbers were then coordinated in a net effect represented in a final stabilization triangle diagram (see Figure 2).
15. Dissemination: Students edited their work into a final 240 page book distributed in electronic form (through Issuu online publishing) and a physical, self-published copy (through Lulu online publishing). The Issuu electronic book has been read 59 times since the Fall of 2016 from IP addresses around the world. Students made presentations to the UA Vice Presidents of Planning, Design and Construction and Facilities, the UA Office of Sustainability, and the 2018 UA Master Plan professional team.

4.0 DISCUSSION: APPLICATION AND RELEVANCE

The stabilization triangle method can be employed to prepare emerging architects to be the coordinators of climate action solutions within their future communities. Additionally, this pedagogical method can help address the existing gap between ACUPCC signatory goal setting and an implementation plan with sequenced and specific financial, policy, and physical actions. Within these two outcomes, the UA case study presents several opportunities and challenges.

4.1. Student Learning Outcome: Pedagogical Challenges and Opportunities

The stabilization triangle method provided a clear structure, translatable to science, policy, and practice, by which emerging architects learned about climate planning. The students gained the new skillset of master planning with resource-based models that incorporated financial strategies and infrastructure realities. One challenge in classroom management was the differing levels of mathematical and computational acumen by design students. Some students quickly understood resource modeling and budgeting, while other struggled. Through partnered assignments and a diverse portfolio of solutions, students participated in areas where they had strengths and weaknesses. In the future, a more careful and conscious matching of students existing skills, desired learning growth areas, and necessary talents for deliverables could be completed. Positively, after the course, two students attributed securing jobs from the hiring employers' specific interest in the studio work and students' exposure to resource modeling and financial thinking.

Students were challenged to integrate various scales of design (i.e. building to district plan to infrastructural network) and various disciplines (i.e. science, policy, financial thinking). Students rose to the challenge of integrating these scales and modes of thinking with the assistance of the professor and visiting professionals who specialize in this line of work. It was a challenge to have students jump from one scale to another or one mode of analysis to another. The integration of professionals and campus administrators was key to supporting students to be open to the challenge and nimble yet clear in their ways of thinking.

Finally, students learned to better link experiential ways of knowing (i.e. their life on campus) with analytical ways of knowing (i.e. carbon and water modeling and projections) with design solutions (i.e. the future physical form of proposed implementations). The UA campus sustainability asset map assignment was helpful in priming students to identify links between the three. In future courses, this assignment could be improved by better integrating current data and future projections into the asset mapping process to more strongly reinforce links between the three.

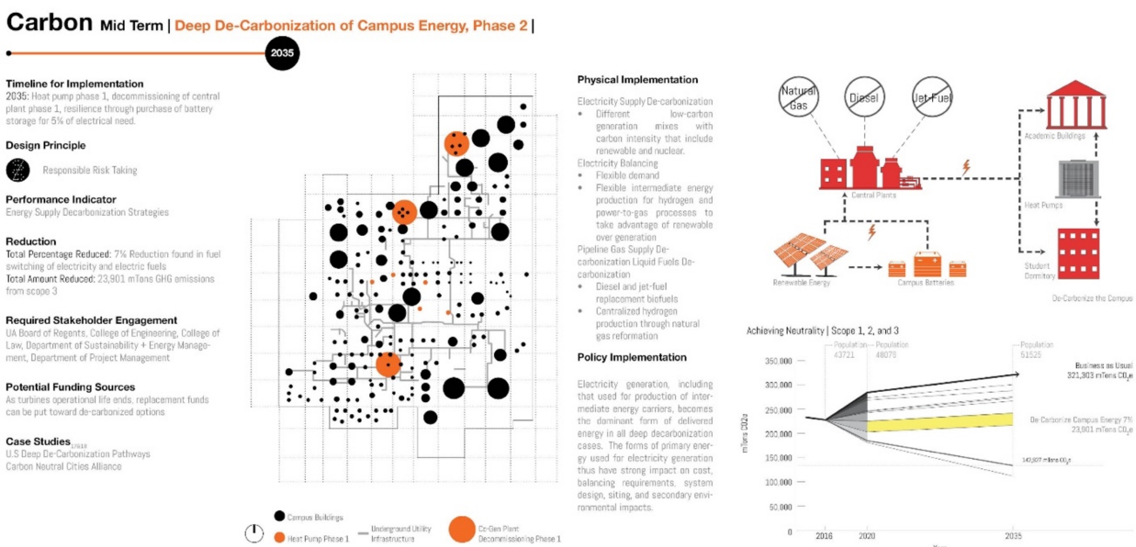

Figure 4: Example from play book for De-Carbonization mid-term(2035) implementation. Source: (Author and UA ARC451b 2016)

4.2. ACUPCC Implementation Outcome: Campus Administration Challenges and Opportunities

The stabilization triangle method is the most widely adopted means by which to project and plan for carbon emissions reduction. This method was successful at communicating the implementations laid out by the students to the campus administration and master planning project team, as evidenced by adoption of the work into the 2018 UA master plan.

Despite clarity of communication of implementations, challenges existed in unifying different staffs across campus in cross cutting implementations, particularly the campus capital projects staff with the facilities staff. Cooperation between campus facilities and capital project teams is a vital partnership for any campus climate action plan to efficaciously implement a portfolio of solutions. A unified commitment to the climate action targets is necessary for success and can be created through an outspoken and clear executive university administrator who persists to focus attention on achieving campus targets. Policy research has found that commitment from the top is one of the key determinants for success of higher education institutions in becoming sustainability leaders (Dyer 2017). From the case study research, campuses that had already achieved carbon neutrality had three unifying factors: (1) small population size, (2) centralized leadership invested in being at the forefront of sustainable campuses, and (3) use of biomass (in a cold climate with adjacent forests) to deliver full 'renewable' energy supply. These three characteristics were poles apart from UA.

Finally, financial barriers were the largest road block to the carbon and water implementations. Students researched and suggested funding mechanisms to campus administration for each implementation in the portfolio of solutions to reduce this real and psychological road block. By sequencing the low hanging fruit first in the timeline of implementations, momentum can be gained and a revolving funding strategy can be initiated. The students also gave campus administration five guiding principles that recognized the difficulty and worth of the task ahead of 2050: (1) Spirited Optimism, (2) Principled and Practical Action, (3) Transformative Thinking, (4) Responsible Risk Taking, and (5) Organizational Effectiveness.

5.0 CONCLUSION

Since the creation of the ACUPCC carbon neutrality 2050 goal in 2006, over 700 colleges and universities have taken the pledge. Over the last ten years of actualization, a common struggle exists within ACUPCC institutions to convert the promise to actionable policy and physical implementations on their campuses. University and college architecture faculty and students have the unique skillset to bridge between target goals and realized change. Using the Pacala and Socolow stabilization triangle method, a portfolio of existing solutions can be coordinated for tangible campus carbon and water action successes. This paper outlines a case study of an upper level UA architecture studio that used an adaptation of this method and created a road map to carbon and water neutrality. Ultimately, such an application can train emerging architects to be the coordinators of climate solutions and support ACUPCC signatories to take the bold steps from intension to short, mid, and long term organized action. This application leverages the unique, fundamental skills of architects as resource coordinators and optimizers to achieve climate action success.

6.0 NEXT STEPS

The UA campus master plan is currently in process. The work by the students will be represented in the plan as a final chapter on sustainability. Focus groups will be held to further integrate the playbook of implementations outlined in the work into the overall professional master plan team's recommendations.

ACKNOWLEDGEMENTS

ARCH 451b Students in Fall of 2016: Tai An, Katie Cooney, Jessica Cuadra, Geng Li, Weicheng Rui, Julianna Sorrell, Brisa Soto, Elizabeth Vickerman, Peitong Zhang, Yelin Zhong, and Rubin Zhou.

REFERENCES

ACUPCC, 2012. Celebrating Five Years of Climate Leadership. ACUPCC Annual Report. Second Nature, Boston, MA.
ACUPCC, 2017. American College & University Presidents' Climate Commitment. www.acupcc.org (accessed 15 December 2017).
Arizona Board of Regents 2015. Annual Report. https://public.azregents.edu (accessed September 2016).
Coulson, J., P. Roberts, and I. Taylor. *University planning and architecture: The search for perfection*. Routledge, 2015.
Dyer, Georges, and Michelle Dyer. "Strategic leadership for sustainability by higher education: the American College & University Presidents' Climate Commitment." *Journal of Cleaner Production* 140 (2017): 111-116.
Harris, Z., H. Moynahan, H. Vickery, H. Henriksen, E. Morello, and B. Kasemir. "Higher Education Strategic Planning for Sustainable Development." In *Handbook of Theory and Practice of Sustainable Development in Higher Education*, pp. 153-164. Springer 2017.
International Living Futures Institute, 2018. Living Building Challenge. https://living-future.org (accessed 13 January 2018).
Pacala, Stephen, and Robert Socolow. "Stabilization wedges: solving the climate problem for the next 50 years with current technologies." *science* 305, no. 5686 (2004): 968-972.
STARS, 2017. Sustainability Tracking, Assessment, and Rating System. https://stars.aashe.org (accessed 13 January 2018)
US Department of Energy, 2015. A Common Definition for Zero Energy Buildings. US DOE, Washington DC.

[i] The book can be found at: https://issuu.com/universityofarizonaschoolofarchitec/docs/chapter_1_2_3_4_5_6_7_8]