Reflections on an Immersive International Engineering Program Focused on Sustainable Energy in Brazil: A Student's Perspective

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Abstract

It is incumbent upon the next generation of engineers to address the issues of climate change. With this, there are many challenges, including understanding our current technologies and the viability of implementing them on a global scale. There is a need to teach global competence skills through international, experiential experiences to facilitate this understanding and learning.

This paper addresses the evolution of a five-week, faculty-led program in Brazil focused on sustainable energy. The 'Dialogue of Civilizations' aims to increase the global competency of Northeastern University students by immersing them in a foreign culture through language, food, and education. The global competencies incorporated into this program were the ability to examine local, global, and intercultural issues, understand and appreciate different perspectives and worldviews, interact successfully and respectfully with others, and take responsible action toward sustainability and collective well-being.[1] Global competencies can be developed through international short-term study abroad programs designed to offer experiential learning opportunities that students may not get in a traditional classroom setting.[2],[3]

This program was designed to offer learning opportunities for the students on global competencies through engineering curriculum, culture classes, and tours of various energy infrastructure facilities around the country which helped the students gain knowledge on major climate issues. Visits included a tour of CTE, a company that works to make LEED-certified buildings; a biomass landfill; energy storage laboratories of the University of Sao Paulo; Zambianco, a sustainable sugar and ethanol plant; Angra, the only nuclear power plant in the country, and others.

Incorporated in the trip was a project where students were split into groups and paired with Brazilian students from the University of Sao Paulo and an employee at CPFL Energia. CPFL is the second largest non-state-owned group of electric energy generation and distribution in Brazil. The program's goal was to solve real issues that the company faces. Solutions were required to be analyzed for economic, political, and social viability.

The main takeaway from this experience can be categorized into two groups: sustainable energy goals and cultural enrichment. Through classroom learning and experience, the prominent barrier to overcome with renewable sources stems from the lack of storage options. Currently, there are no means for on-demand energy in a sustainable, economically favorable, and practical manner. With respect to cultural enhancement, the authentic program allowed each student to see the world from a different perspective. The combination of travel, classes, and applied learning expanded the knowledge of the traveler past academia.

Introduction

Engineering is often seen by outsiders as a discipline learned through extensive time in the library, crunching numbers, and drawing diagrams. However, this narrative is turned on its head by Northeastern University. An institution built on the fundamentals of experiential learning, this five-week summer program challenges students to use the full extent of their resilience to tackle eight credit hours and adapt to living abroad. The chemical engineering-specific dialogue,

Sustainable Energy in the 21st Century Brazil, offered two rigorous engineering courses and company visits while traveling to southern Brazil. The program was set to visit five major locations; São Paulo, Rio De Janeiro, Foz do Iguaçu, Angra, and Paraty from July 5th to August 13th. The first two weeks were a deep dive into the curricula, whether that was engineering or Portuguese language crash courses. We were introduced to CPFL, the Brazilian energy company we would be paired with for the next month. After the initial two weeks, we flew to Foz de Iguaçu and visited the world's largest waterfall by volume, then to Rio, Angra, Paraty, and back to Sao Paulo for the final presentation of our projects. While engineering was at the forefront of our program, cultural enrichment was plentiful. We learned about capoeira, the history of favelas, toured jungles, visited a UNESCO world heritage site, and saw the largest land rodent. Most importantly, we witnessed the possibilities of sustainable technologies that strive to overtake the massive oil industry.

Engineering Curriculum

The two courses offered while abroad in Brazil were Conservation Principles and Energy Systems. Conservation Principles is a foundational chemical engineering course based on the ideas of mass conservation in simplified industrial processes. This course starts by introducing students to the ideas of chemical composition and mass balances. From there, we venture to diagrams of chemical mixing tanks. As the course progresses, intricacies arise, including reactants or bypasses, multiple intakes, or recycles and purges. Energy systems was an overarching course based on surface-level energy-producing engineering processes. The course continued with the ideas of batteries, magnetism, and combustion to the different kinds of electrical systems. Furthermore, as each system was discussed, ethical debates on producing these power plants induced student-led discussions.

These two courses perfectly aligned with our company visits. In Conservation Principles, the main bulk of the class was based on chemical mixing tanks and the diagrams associated with these processes. At a biogas plant, the group visited, a 12-tank diagram with every intake and outtake was presented. Every student could understand the layout and perform calculations relevant to the flows throughout the system. This illustrated the real-world application of the foundational course being taught. As for Energy Systems, the application was much more direct. The lecture the morning before a company visit would directly relate to the activity in the afternoon. For example, a lecture on fossil fuels would be given in the morning if we visited an offshore oil company later in the day. The combination of lectures, company visits, and travel required adaptation in every student to fully synthesize our learnings.

Included in the program were language and history classes, taught one to two times a week by members of the Brazilian community. A prominent objective of the program was to immerse students in a foreign culture and allow them to appreciate the engineering curriculum in a new space. These language and history classes allowed us to do just that. By learning the basics of Portuguese, we could acknowledge those showing us generosity throughout the visits. A simple greeting and thank you went a long way, and in the end, the experience would not have been the same without them.

The history lectures also proved an exciting twist on learning about sustainable energy. Brazil's independence from fossil fuels stems from the war in the Middle East. The conflict drove most countries into an oil recession that caused much economic strife. Brazil, however, adapted and transitioned away from its reliance on fossil fuels. They were able to build the Itaipu dam, which they share with Paraguay, and the single dam accounts for 15% of Brazil's energy. In addition to the dam, they implemented ethanol more heavily and other governmental policies to encourage the use of renewable energies throughout the

country. Appreciating why Brazil became a sustainable leader was essential to understanding what lies ahead.

Visits

Northeastern's separating factor is the push for experiential education, and this priority is shown brightly in the Sustainability in the 21st Century Brazil Dialogue of Civilizations. As well as eight credit hours instructed, students experienced numerous visits across the south of Brazil. These ranged from visiting Brazilian Universities to energy processing plants. Traditionally, a weekday would be structured as four hours of a morning lecture, a quick lunch, and a bus to a visit, whether that be a university, power plant, or historical site. With over 15 visits completed over the course of the program, below are the six most formative visits of the Dialogue to the cultural, scientific, and historical enrichment of the students.

Biogas

One of the first visits the group embarked on was to a biogas company outside of Sao Paulo called Eva Energia. This plant produces 5 MW of sustainable, clean energy [4]. On the journey, we were shown the landfill, which besides the smell, looked identical to the grassy hills surrounding it. The only defining characteristic was the pipes that stemmed from the ground around the wasteland. These pipes were fed from the compact landfill to the site, where it was refined and used to generate electricity through combustion. Eva Energia contributes to the decarbonization and decentralization of the energy sector of Sao Paulo, which are the main goals of the city and sustainable energy sector. Giving the country options of where it sources its power allows us to consciously choose clean power while maintaining the lifestyle that we rely on. Eva Energia plans to build two new plants surrounding Sao Paulo that will ultimately produce 19 MW of energy using residents' waste. This company was a major proponent in recognizing the current habits we have and striving to create clean energy from them.

Prio

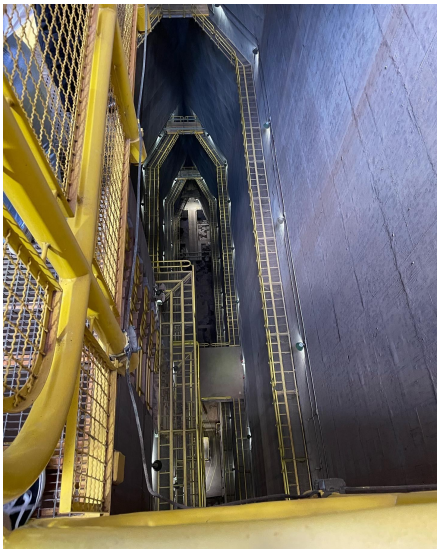
Petrol Rio, or Prio for short, was a premier Brazilian oil company based out of Rio de Janeiro. A relatively new company, they are based around bringing sustainability to an unlikely industry, fossil fuels. Brazil has a massive oil field off the southern coast, with oil tycoons like Shell and Chevron owning drilling sites. Prio's primary business model is buying old or failed wells from these major companies and revitalizing them to maximize profits. This is done in two main ways; major engineering projects and smaller bookkeeping cuts that add up over time. During the time of visitation, Prio had completed a two-mile-long tieback that effectively combined two oil wells into one, saving millions of dollars [5]. Furthermore, they bought a leaking well and got it back to its previous functionality by repairing the damage. In the next five years, they are projected to be one of the largest oil companies in the southern hemisphere. Prio's engineering team was majorly women and had beautiful facilities, facial recognition software, and boasted tons of awards. On a trip based on sustainability and renewable energy, having Prio play devil's advocate and portray the billions of dollars made per year in oil was an eye-opening experience.

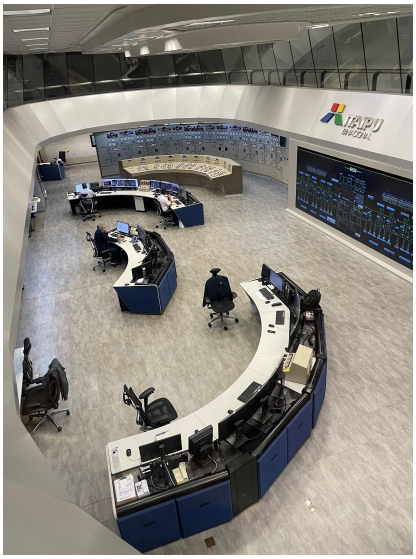
Angra

Currently, there is only one nuclear plant in Brazil. This plant is named Angra, which alone produces three percent of Brazil's power [6]. There are two nuclear reactors in the plant, Angra I and Angra II, located on the eastern coast of Brazil between the cities of Sao Paulo and Rio de Janeiro. We were fortunate enough to visit the plant and understand the prospects and limitations of nuclear energy. The visit began with a presentation outlining the intricacies of the plant and how they strive to keep the area safe. It was prevalent that a large portion of their energy was spent on the storage of nuclear waste and the prevention of nuclear disasters. The scientists explained that the plant was located on the ocean in order to ensure an ample water supply in the event of a meltdown, and the constant supply of water to the reactor allows the system to be kept at a safe temperature. After the presentation, we were granted a tour of most of the plant, venturing as close to the reactors as possible. We were also shown a control room prototype where interns spend around two years ensuring that each person with jurisdiction over the plant knows how to handle every situation. A primary limitation of nuclear energy is the view in the eyes of the public. There is a large hesitation to using nuclear energy due to the dangers that it possesses, but this tour showed us that immense precautions are being taken to prevent meltdowns. Based on this tour, it is prevalent that we will need nuclear energy as a society to transition away from fossil fuels. It may not be the end goal, but the massive amount of electricity these atoms hold may be the key to a green future.

Itaipu Dam

Hydroelectric energy is the primary source of clean, renewable energy in Brazil. The Itaipu Dam, located on the Parana River on the border of Paraguay and Brazil, harvests approximately 10.8% of Brazil's energy and 88.5% of Paraguay's energy [7]. During our visit to the Dam, we learned about not only the feat of engineering construction but also the thousands of people the building displaced. Educating the students on the cultural and technical sides of the building was crucial to rounding out our learning experience. The Itaipu Dam harnesses energy from the Itaipu Reservoir, the seventh-largest reservoir in Brazil. The water flows through the dam, spinning turbines deep below the surface and generating electricity. Just downstream from the dam is Foz de Iguacu, wondrous waterfalls that reveal 360-degree views of stunning waterfalls. On average, 1.1 million L/s cascade down the falls, an unfathomable amount of water that we were fortunate enough to witness. At Itaipu, we were given a full tour of the facility, even venturing down into the depths of the dam to see one of the full-speed turbines in action. We learned how the dam splits its energy sales from Paraguay and Brazil evenly, and Paraguay sells most of the harvested energy back to Brazil for profit.





Zambianco

Ethanol plants are an extremely important source of energy and fuel in South America. At each gas station in Brazil, high ethanol concentrated gasoline is offered. While it still releases carbon dioxide when combusted, ethanol production is much safer and more renewable than fossil fuels. The effects of deep sea drilling or fracking on the environment are exponentially more dangerous than ethanol production from sugar cane. The process begins with sugar cane waste material being trucked to the facility. These sugar cane husks are then compressed; the products are the sugar cane juice and bagasse, the dried, compressed sugar cane husk. Production then splits into two factions; the bagasse is burned under turbines to create electricity, and the sugar cane juice is reduced and boiled down into a high alcohol content liquid [8]. Throughout the visit to Zambianco, the students were able to see every single step of the process. The sugar cane was trucked in, crushed, and processed in front of their eyes. The students were able to climb the four-story boilers and mixing tanks, smell the sugary intermediate liquid, see the lab that tested the ethanol in small batches, and even were able to take a bag of sugar home with them. This was a quintessential visit for the students as it directly related to the course being taught. A full diagram of the mixing takes intakes and outtakes illustrates the ideas of Conservation Principles on a macroscopic scale. Ethanol was discussed in length in Energy Systems because while it is a renewable resource, it is still a combustible fuel source, which still produces harmful gasses. Ethanol production is a major energy source in Brazil, and while sugarcane is not a viable crop to grow for fuel production in the US, a similar plant could be used to topple the fossil fuel industry. The visit to Zambianco was a prime example of the difference that experiential learning can have, especially in engineering. In the classroom, only diagrams and models could show this entire process. In Brazil, we could climb four-story distillation towers, see the direct split to the furnace and the refinery and the furnace, and smell the sweet aroma that comes from the creation of sugar. This immersive learning allowed students to witness an engineering marvel that is a high prospect in the generation of sustainable energy in Brazil.

Governor's office

The governor’s office visit was an extremely important one to show the non-technical side of engineering to students. Policy shapes all forms of engineering indiscriminately, regardless of the technical side of the discipline. When the group visited Rio de Janeiro, the students were invited to the Governor’s palace. After touring the historic site and perfectly manicured courtyard, the students were greeted by a panel of politicians based on sustainability and energy consumption. Each politician introduced themselves and their credentials and then gave a short presentation about the usage and statistics of renewables in the city of Rio. The most enriching part was a Q & A section after each presentation. Whether it was about bills to phase out fossil fuels, promises to teach sustainability in grade schools, or updated public transportation plans, all of these questions were answered to the best of their

abilities. Students were able to gain a better understanding of the work that goes into policy-making and compare and contrast the ideals and foundations of laws between Brazil and the United States.

CPFL Energia

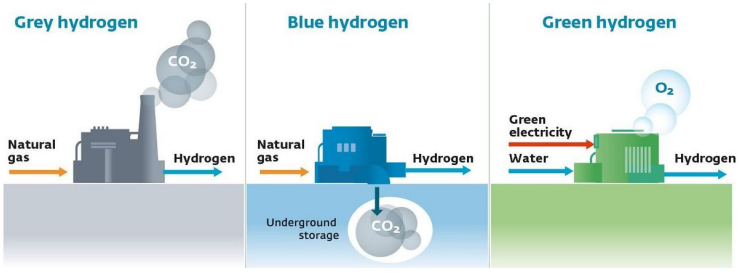
CPFL is a premier energy company based in the suburbs of Sao Paulo. This company's primary goal is power generation and exportation across the entire country of Brazil. The headquarters visited on the Dialogue of Civilizations was mainly tasked with researching and monitoring the company. These headquarters consisted of 3D models of their grid system, holographic information about the company, an electric car fleet, and a 24/7 control room monitoring the regional grids. When the grids fell or failed, teams were dispatched to fix the issue and allow energy to be reconnected to the compromised areas. The students paired with CPFL were given four challenges to solve; macrophyte overgrowth in hydroelectric sectors, green hydrogen usage, tree pruning around power lines and how to effectively use the tree waste and recycling of packing materials used to ship generators. These students, paired with a mentor in CPFL, participated in a one-month problem-solving challenge to see the viability of different solutions to the problems presented. These solutions were then presented to the company and will later be implemented.

<u>CPFL Project 1 -- Green Hydrogen</u>

The first project the students in this program completed was about green hydrogen. CPFL tasked us with researching the limitations, current practices, and their impact on society and economics. The company had researched green hydrogen and was looking to expand its investment and technologies further into the industry.

Our project was split into six sections; how green hydrogen works, an overview of the current practices, government policies relating to green hydrogen in Brazil and the US, and three solutions to the problems. Storage, transportation, and production were the three sectors we chose to focus on to improve. A brief overview of the obstacles and solutions is described below.

Making green hydrogen uses water electrolysis to separate oxygen and hydrogen. The only byproduct of electrolysis is oxygen, and by using energy from sustainable sources to power the process, the hydrogen created for combustion is entirely carbon neutral. The issue with this method of sustainable energy comes from the storage, transportation, and gas production costs. Electrolysis is not cheap, and when you have an abundance of hydrogen gas, it must be kept under high pressures and low temperatures to ensure its stability.



The current government policies for green hydrogen are slim, but not none. In the US, the IRS rewards tax breaks to companies that use renewable sources to power their production. This includes

using green hydrogen, along with solar, wind, or any carbon neutral energy. In Brazil, the government invests in green hydrogen production facilities to enhance existing infrastructure. Although some action is being taken in both countries, if there was more of an investment in this product, it may be a prominent proponent in saving the world.

The primary issue with green hydrogen is the energy loss that occurs when using a multistep process to store sustainable energy. If a solar farm produces more energy than is needed, it is incumbent that it is stored for future use. Green hydrogen is a great way to do this, but there is a loss of energy that occurs when you transfer energy from one modem to another. It is unreasonable to rely solely on green hydrogen to power our grids. Still, if it is possible to make it economically viable, it may be an excellent replacement for batteries and other harmful methods of energy storage.

The second problem that arose in our research was storing the gas. This gas must be transported and stored at very high pressures and low temperatures, making it a combustible and dangerous method of renewable energy. The solution to this obstacle was an oil called Liquid Organic Hydrogen Carrier, or LOHC. This is a non-flammable oil that can be transported without the dangers of combustion. The process of condensing the hydrogen gas into LOHC and vice versa is relatively simple; however, with each state change, there is bound to be a loss in energy. With our research, this is an economically viable option, and with more of an investment, it could solve the issue of storing hydrogen gas.

The last objective to tackle was production. Electrolysis is expensive and will only thrive if we can reduce costs. We researched many promising up-and-coming hydrogen production methods, the most notable options being methane pyrolysis, photolytic processes, and photolytic biological pathways. All of these methods need to be researched more to determine if they can produce green hydrogen at the desired rate and efficiency. Still, they are all economically and socially acceptable options.

This project dove deep into the storage of renewable sources, one of the most prominent obstacles in the sustainable energy transition. Although no definitive answers were found to make green hydrogen the primary source of global energy, we all learned a ton about the industry and continue to discover new ways of creating a green planet.

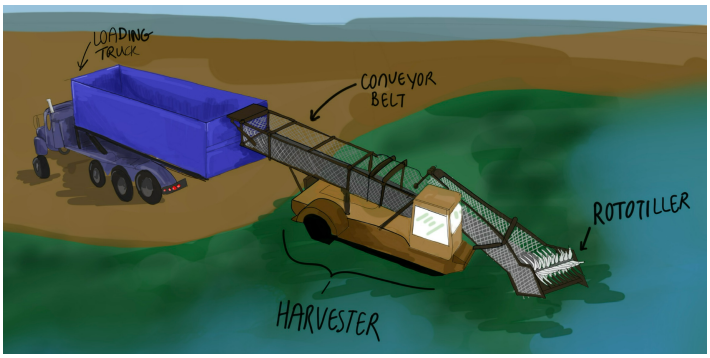
<u>CPFL Project 2 -- Macrophyte Overgrowth</u>

A second major project students did in Brazil was problem-solving macrophyte overgrowth in the Atibaia river. CPFL had created a dam to generate electricity to sell off to the surrounding areas. However, this created unforeseen problems. The lake was a primary recreational and food source through aquatic plants and fish. However, in the wet season, runoff of fertilizer and sewage created an influx of

nitrogen into the now stagnant river, creating peak conditions for an algae bloom. Traditionally, the running water of a river would mitigate this issue, but the dam's stagnation of the river allowed for this bloom to occur. In the months of the dry season (August to February), macrophytes bloomed through the entirety of the water column, with hyacinths clogging the surface and spirogyra filling in the lower water columns. This created clogging in the turbines of the dam and rapidly depleted oxygenation in the lake, creating toxicity of the water. This severely impacted the fish and other wildlife, causing the Brazilian government to begin fining CPFL and tasking them with fixing this issue.

The current strategy of CPFL was mechanical removal. This was done by a fleet of boats, excavators, and trucks to remove the excess macrophytes from the lake and leave them to dry in the sun to remove the water weight of the plants, which can be up to six times heavier when waterlogged. While this was an effective strategy to get back within government regulations, it was extremely inefficient; emissions were released at high rates from the heavy machinery, the macrophytes had to be dealt with after removal, and the lake is still toxic, limiting recreational activities. Students were tasked with presenting solutions to solve this problem and performing a cost-benefit analysis for each solution.

Solutions fell into three categories; streamlining the mechanical removal, reusing the macrophytes, or preventing overgrowth. For streamlining removal, the main solution was a prototype boat that would eliminate the need for excavators. It could collect, drain, and offload the macrophytes into trucks on land. This saves costs by eliminating diesel for excavators, wages for labor, and the need for more complex machinery on site. The next idea would be to use the macrophytes in fertilizer. Since macrophytes feed off nitrogen and oxygen, they are extremely effective in promoting plant growth when dried and ground into fertilizer. However, CPFL would need a 3rd party fertilizer company to assist in producing and retailing fertilizer from the top water hyacinths. The final solution was based on prevention. This could be done in 3 ways; legislation, chemical treatment, or water surface disruption. Sewage and fertilizer treatment was highly unregulated, which was the root of the problem. While this would be an easy solution to just stricten regulations, the enforcement would fall on CPFL or government task forces, which was improbable. Chemical treatment was an idea that was presented, but because the lake is a recreational hub, this was quickly dismissed.



The most viable option was a surface-level disruptor, whether this was an underwater bubbling system or a traditional fountain. This would artificially simulate rain, which traditionally breaks up stagnant water and inhibits the spreading of surface-level macrophytes. To outfit the entire lake with a bubbling system would cost around 500,000 United States Dollars. However, this technique could be concentrated around the dam to stop the macrophytes from clogging turbines for much smaller costs. Combining this aeration system with the above boat allows macrophyte removal and prevention, revitalizing the lake.

Cultural Enhancement:

<u>In versus out of the classroom:</u>

Throughout the program, we were presented with many opportunities to immerse ourselves in Brazilian culture in and out of the classroom. In the classroom, we had culture classes that consisted of history teachings and language basics. These experiences allowed us to apply our knowledge on visits or other non-academic related endeavors. One of the most notable experiences was a favela tour in Rio de Janeiro. This visit allowed us to see the lives of the vast majority of the Brazilian population, not just the curated programs created by the University. Using the knowledge of the history learned in the classroom, the favela was an enhanced experience that was a highlight for many students on the trip. As engineers, we can rarely piece together cultural learnings from the classroom with outside knowledge. Still, this Dialogue of Civilizations did a fantastic job ensuring we experienced every aspect of Brazilian life.

Traveling to Brazil as a young adult came with its own challenges. The most difficult part was the language barrier. Portuguese, specifically Brazilian Portuguese, is an idiom not offered in many American schools and sounds extremely different from Spanish. While many Brazilian citizens spoke English, relying on hand signals, broken Spanish, and, most importantly, Google Translate was an added challenge outside the classroom. This trip further pushed me out of my comfort zone in all facets of the saying.

In Foz Do Iguaçu, I could take a boat under waterfalls and see exotic animals, notably the Capybara. In Rio De Janeiro, I was able to surf Copa Cabana with locals, a dream come true, as well as tour all parts of the city to gain an understanding of the vast wealth disparity. In Paraty, I was able to interact with various genders within a city market to understand a small portion of the vast culture Brazilians uphold each day. Our local guide, Renato, was integral to our entire experience, conveying the intricacies of Brazilian social dichotomies, systemic racism from the slave trade, and oppression of marginalized groups.

While this trip was marketed as taking two Chemical Engineering courses abroad and a case study with an energy company, it transformed into being so much more than that. We could play basketball among locals in the country's largest park, see one of the Wonders of the World, and have fun every step of the way. Making lifelong bonds with Brazilians and my classmates is an opportunity that would not be achievable strictly within the walls of a Boston-based classroom. These experiences made me a more competent cultural citizen, and pairing engineering curricula with exposure to unfamiliar territory truly augmented my abilities as a global student.

<u>Differences in the US and. Brazilian culture and how they relate to policies surrounding sustainable energy applications</u>

Due to many needing access to clean water or electricity, Brazil is still a developing country. We saw many instances of locals needing to have the same privileges of basic needs that we do. The development of sustainable energy and other aspects of the country is creating opportunities for people with less to receive cleaner and cheaper energy than those provided by fossil fuels. The government is working to increase all sources of clean energy, and in the long run, they will grow with the use of renewables. There are many policies in the government and incentives for companies to go green with the ultimate goal of creating a society that relies on clean energy sources for all communities in need.

The US is a developed country and one of the main economic powerhouses of the world. We rely heavily on fossil fuels to run our world as we know it. This is the main difference between policies surrounding sustainable energy in Brazil and the United States; One must come up with solutions to stray away from a fossil fuel-driven economy, and the other is working towards growing their economy around using clean energy. The United States has some incentives, such as carbon credits, to encourage large and small businesses to go green, but the action that needs to be taken has been repeatedly put on the back

burner. Many Brazilian companies know the climate action policies that help their business and the country, making it easier for companies to go green. The culture in the United States does not include green energy, which is an action that needs to be changed now.

Conclusion:

Solution Application:

From the knowledge learned in Brazil, nuclear implementation would be the clear solution to the energy crisis plaguing the United States. Brazil harnesses much of its power from hydroelectric, but increasing droughts and little to no major river presence in the United States limits the output through dams. Smaller turbines could be utilized to limit the number of fossil fuels needed, but more is needed to impact the oil industry significantly. Furthermore, wind and solar panels can be utilized in the Midwest. Still, with the US using over four trillion mWh per year of energy, weather-dependent sources could be futile in a fight to limit combustible sources [6]. The US has the advantage of having most of its major cities (New York City, Los Angeles, San Francisco, and Boston) coastal, allowing nuclear energy plants to be very practical. Angra was an exemplary plant because the easy access to seawater to cool off the reactor allowed the energy system to work at ideal temperatures and conditions. The North Atlantic would allow even cooler feed water, creating a safer environment for nuclear reactions. It can distribute energy created to New York City and Boston with minimal losses that may occur to large transmissions across state lines. The same concept can be applied to the western coast of the United States. Massive amounts of energy can be created by utilizing the Pacific Ocean as a feed for these plants. Furthermore, some of these plants can be combined with desalination to aid in major droughts the west coast is facing. With the US only having around one-third of all energy produced through renewable sources, to have a major effect on the climate crisis, this must increase significantly before catastrophic weather events and major sea level rises occur.

Engineering Curricula:

Through our learning in the classroom, we were able to understand and immerse ourselves in the sustainable side of Brazil. Our classes created an environment to thrive and see exactly why our learning mattered. The two core courses, Conservation Principles and Energy Systems, coincided with our visits and tours. Through the knowledge of Brazil's culture and history, we could appreciate every part of the trip. Working with Brazilian students to solve real-world problems for a prominent renewable energy company allowed us to excel in our problem-solving skills and think outside the box. Overall, this trip was planned perfectly and created an immersive environment where engineering students could excel in and out of the classroom.

Global Competencies:

Throughout the program, global competencies were developed and cultivated through visits, interactions, and discussions. These competencies were the major framework that created the itinerary for the entire program. As mentioned in the abstract, 4 primary global competencies were fostered over the 5-weeks to transform each student into a fully functioning global member of society. The first of which was the ability to examine local, global, and intercultural issues. Company visits developed this in many ways, but most prominent in the students' visit to Petrol Rio, or Prio for short.

The ability to understand and appreciate different perspectives and worldviews was developed by communicating and empathizing with members of different cultures. Throughout the experience, we were fortunate enough to see a multitude of economic and social backgrounds. From favelas in the heart of Rio de Janeiro to tours of Nuclear power plants on the coast, we were guided through many sectors of a culture so different from our own. The emphasis on sustainable energy in the business economy, the sense of unity while walking through the streets of the city, and getting to know our peers and professors was a special experience that opened our eyes to the world around us in a new way. We returned from the trip ready to inspire change and become more tolerant and motivated citizens of our own country.

Working with Brazilian teammates and the Brazilian mentor developed the ability to interact successfully and respectfully with others. The language barrier is one of students' biggest challenges when going abroad. To further perpetuate this issue, Portuguese is often not an option in many United States public schools. Therefore, conveying engineering ideas, a topic that is already complex, exponentially increased in difficulty. It took a major sense of empathy to grasp the challenge that Brazilian students were having fully. To communicate in your non-native language all day with fluent speakers is draining, compounded by the stress of meeting project deadlines; students must take a step back and reflect upon the struggles of others. Additionally, the Brazilian mentor was another interesting dynamic that must be navigated. They were the head point of communication for all case studies and relayed sensitive information about the CPFL's internal struggles. Navigating these foreign relationships effectively determined the group's success. Being able to synthesize information, grasp advanced engineering concepts, and traverse a language barrier were integral to an efficacious case study.

The ability to take responsible action toward sustainability and collective well-being was developed through our coursework and its direct relation to the guided tours. Many students go through their academic careers by listening to a professor on the chalkboard and reading the textbook. It is not until they enter the workforce that they get to implement their learnings. With this program, we could take what we learned in the morning and see its play in the real world mere hours later. The emphasis on sustainable energy forced us to look at the world's climate issue head-on and use our skill set to problem solve. We could also see how other people had done the same thing and made their life's work saving the world. Each plant we visited inspired us to elevate our learnings, be passionate about what we have the potential to do, and be awed by those who had taken it upon themselves to be innovative and brave in the face of a seemingly impossible problem.

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