Germany Report

Abigail Ondeck

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1. Goals of My Experience

Germany is very advanced in renewable energy, with approximately 25% of their power generation currently provided by renewable energy sources. On October 3, 2013 at noon, wind and solar power peaked at 59.1% of German power generation. The large increase of renewable energy is partially due to large incentives to install renewables and a guarantee that renewable energy can be fed to the grid at a minimum price. I am interested in seeing how Germany has incorporated renewable energy in their grid, along with the effects of intermittent renewable energy on the grid and how it is controlled. I am currently working on modeling and optimization, and in the future control, of a Combined Heat and Power (CHP) plant for a residential neighborhood, using data from the Mueller neighborhood. I plan on incorporating renewable energy, such as solar power and geothermal, into the model and determining the best way to use the energy to increase efficiency and level peaks. I want to learn from Germany the impacts of mass renewable energy on the grid and energy production to see how it could affect my CHP plant model.

In addition, Germany has a different approach to energy use than Texas. The summer temperatures in Germany are not as hot for such a long extent of time, so A/C units are not used as often and the thermal cooling load is not as high as is Austin. I am interested in comparing Austin energy use and Germany energy use to see the effects on my CHP plant model. Since the model plant is optimized to match the thermal load, the different components of the CHP plant and the method of using renewable energy in the plant could change.

Studying in Germany would be very beneficial for my research. TUM in Munich has many great professors that work in the energy field and also has many different areas that address energy production, use, and efficiency. One area of great interest to me is the TUM Energy: Center for Power Generation. Dr. Hamacher is conducting research on micro-CHP for domestic energy supply. This includes simulation and optimization of micro-CHP. He also has access to real data on buildings and inhabitants including single and multi-family houses, which I could use to see how my CHP plant model, optimized for Austin, reacts to Germany's electrical and thermal needs.

Outside of TUM research, I am interested in seeing how Germany incorporates renewables into their residential neighborhoods. I also want to go to a few conferences to see if there are any new control and optimization methods that would be better for my CHP plant model, such as the Renewable Energy World Conference: Europe and the European Controls Conference. Studying and researching in Germany would be very beneficial to my research and education by broadening my knowledge of different environments and energy policies.

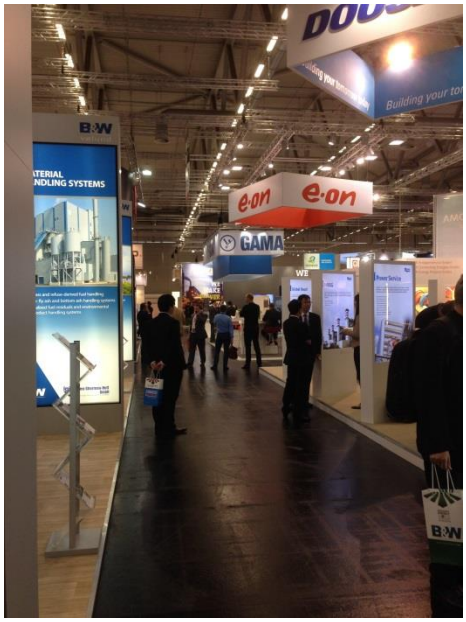
2. Conferences

2.1 PowerGen Europe: Cologne, Germany

PowerGen Europe is an exhibition and conference that concentrates on electric power generation. It is also held in conjunction with Renewable Energy World Europe, an exhibition and conference on the potential for renewable energy, including biomass, solar, energy

efficiency, etc. By registering for this conference, I was able to attend both PowerGen Europe and Renewable Energy World Europe. The Power-Gen Europe conference was enlightening. However, it seemed more like a place for companies to talk about their specific equipment and try to sell it to companies that are looking to build a plant. There wasn't much concentration on future research. I attended 8 different sessions over a period of 3 days. The following topics were covered along with a few major points from each session:

1. A Strategy for a Changing Power Sector
    a. Despite Germany trying to change their energy generation to use more renewables, they have actually increased their CO2 emissions in the past 2 years because of the increased amount of coal used to offset turning off their nuclear plants.
    b. Utilities profits in Germany get a lot of their profit from subsidy harvesting because generating electricity has now become unprofitable due to the unregulated market (the prices are very volatile and often go below the profit margin due to overcapacity and renewables).
2. Combined Heat & Power
    a. Natural gas power plants require incentives to make profitable.
    b. The big problem with CHP (with heating) is that the load in the summer is basically non-existent (only for hot water).
3. Combined Cycle and CHP Operational Flexibility I
    a. The biggest challenge with CHP and heating is how to decouple the heat and the power.
    b. The main concentration on CHP at this conference is not in revolutionizing the process, but making the electricity production more efficient.
4. Combined Cycle and CHP Operational Flexibility II
    a. Non-regulation of electricity markets and high cost of natural gas in Germany are making subsidies necessary to run more efficient CHP plants.
5. Navigating the Power Transition (joint panel discussion)
    a. Small plants will be used to replace larger plants that are not profitable anymore.
    b. Biggest question to be addressed is how to pay for distributed generation.
6. Decentralized Generation & System Integration
    a. Integration of large amounts of renewables (PV and wind) has caused profit losses to all power generation plants.
7. Energy Storage
    a. LAES (Liquid Air Energy Storage) is what people are looking towards to store both heat and cold for energy storage in Europe.
8. Policy, Regulations & Capacity Mechanisms
    a. The grid needs reinforcement (in Germany).
    b. Germany has low CO2 certificate prices, making coal a cheap fuel.
    c. Germany is placing "breathing caps" on renewable generation, so that they will have to generate so much energy, or the tariff associated with that renewable will be increased.



Exhibition floor at the PowerGen Europe Conference

2.2 European Control Conference (ECC): Strasbourg, France

The European Control Conference (ECC) is a conference that covers a lot of different aspects of control, from theory to application. Over three days, I attended many different sessions. The sessions I found the most interesting/useful were the following:

1. Coordination and Consensus Agreement in Dynamical Systems I
    a. In one of the talks, A Message Passing Algorithm for the Evaluation of Social Influence, the maximum influence of any node is one that blocks off competitors from the rest of the network.
2. Model Predictive Control (MPC)
    a. Biggest problem with MPC is to have a solving time that is shorter than the updated time, which is hard for non-linear problems with fast time steps.

2.3 IGSSE Forum 2014 - International Research: Opportunities and Challenges (Burghausen, Germany)

The IGSSE Forum is a forum held each year by TUM to help connect its students that receive the International Graduate School of Science and Engineering (IGSSE) scholarship, and educate each other on the research that is happening at the international level. This year's topic was Opportunities and Challenges, and the goal was to highlight the range of possibilities that come with research across borders. All of the students in Germany at IGERT attended the event along with students from the University of Texas Architecture school that were studying in Munich for 6 weeks. Everybody in attendance was divided into four different workshops: Computational Science and Engineering, Biomaterials, Water, and Green Technology/Energy Systems. The Green Technology/Energy Systems was a mix of students from the UT Architecture school, UT IGERT group, and TUM energy students (electrical engineering/chemistry majors). We divided

into two groups, and created an overview of the energy/green technology sectors in Texas and Munich. The groups were a mix of both Germans and Americans, so we all learned about each other's countries.

Left: Participants from the IGSSE Forum. Right: IGERT members at the Raitenhaslach monastery at the IGSSE forum

The conference was very nice and promoted socializing among all different types of people. From all of the activities, everybody got to share their thoughts and expertise in their area so that everybody could benefit and learn. At the end, a dinner was held at the Raitenhaslach monastery, where TUM is renovating one of the old buildings to use as offices and classrooms for the science department.

2.4 "Energy in Motion" - 4th Colloquium of the MSE

Each year, TUM hosts a Munich School of Engineering (MSE) colloquium on Energy. The colloquium is a one-day event full of speakers, presentations, and a poster session. The keynote speaker from ExxonMobil, Olaf Martins, was very interesting. He gave a talk on the Shale Gas Revolution, which is not big in Germany since it has little natural gas, and mainly concentrated on the United States and the Eagle Ford Shale region. I myself participated in the poster sessions during the day. I worked together with a student from TUM, Simon Herzog, and created a poster, Storage and PV Integration in CHP Facilities for Residential Neighborhoods. This poster contained work that I did in Germany, using my CHP plant model and Mr. Herzog's storage models.

3. TUM Classes

While at TUM, I registered and took 2 classes: Integration of Renewables, and Advanced Topics in Sustainability Innovation and Marketing.

The first class, Integration of Renewables was very useful and educational. The goal of the class was to provide an introduction to renewables, with a concentration on the current renewable and energy sectors in Germany. The class covered the physical, system, and market integration of renewables in the German energy sector. From this class, I learned how different the German and the American energy sectors really are. Germany does not have access to the same fossil fuels like the United States and use mostly coal to power their power plants. Instead of cutting back on coal to lower their CO_2 emissions, the government enacted a policy to cut nuclear after

Fukushima. Since then, they have had to increase their coal use to cover the electricity that must now be produced by coal power plants. It seems like their biggest problem, in addition to higher coal use in power production, is updating their current grid to be able to deal with the large increase of renewables. A lot of their renewable electricity generation is found in areas that are not populated. In order to use this electricity, a new transmission system is needed to a) move the electricity to areas where it is needed, and b) to create a stable grid with the large amount of renewables. The only grade for the class was from a final at the end of the semester.

The second class was Advanced Topics in Sustainability Innovation and Marketing. In this class, I studied the complexities of sustainability issues and how they are integrated in entrepreneurship, innovation, and marketing management. After learning about the current automobile situation in Germany, particularly car sharing, I, along with three other group members, completed a case study on the sustainable entrepreneurship process (SEP) for ZebraMobil. ZebraMobil was a car sharing company to create floating parking, where cars could be parked anywhere in the city, as long as it was in a public parking space. However, due to lack of funds, they were unable to purchase the necessary car fleet that would allow them to compete with bigger companies that copied their floating parking, such as BMW. The project was comprised of a presentation and a final paper.

4. Interactions with TUM

4.1 Research

While in Germany and taking classes, I spent my time in Dr. Hamacher's lab. Dr. Hamacher is the head of the Renewable and Sustainable Energy Systems and a professor in the Electrical Engineering and Information Technology department. I worked closely with one of his students, Simon Herzog. Simon and I worked on a joint project to combine his energy storage models with my CHP plant model. His models were dynamic, so I had to change my CHP plant model and make it a dynamic optimization (it was originally static). The two types of storage we used were electrical (battery) and thermal (ice). The results of this project we presented at the MSE Colloquium (Section 2.4).

I also made useful connections with other students in Dr. Hamacher's lab, with who I will be in contact in the future. These students worked on micro-CHP plants to be used with only 4-5 houses, but their research on costing/sizing of the CHP plant might be useful with my research in the future.

4.2 Meeting Other Students/Labs

I took the time to visit a few other labs at TUM using contacts that I made at TUM events. One lab that I visited was Audio Signal Processing. Here, they are working on using audio signal processing to find flaws/problems in wind turbine blades. This will make the detecting and identifying process much faster than it is currently, where people use mallets and the bare ear to try to determine faults in the blades.

I also met with several students from the TUM campus located in Singapore. TUM has a satellite campus in Singapore, with a lot of graduate students doing research in many different areas. A few of the areas of research include:

- Tracking of taxi traffic routes to determine the optimal location of charging stations for EV taxi cars.
- Increasing solar panel efficiency in semi-cloudy conditions
- Battery safety (determining the conditions that will make different batteries unsafe)

5. CONCLUSION

After spending almost four months in Munich/Europe, my trip was very beneficial. I have achieved the following on my trip over that I feel are important for my future as a researcher:

1. I have a greater knowledge of the energy sector in Germany and in Europe so I can make comparisons between their energy sector and the United States'.
2. I now am familiar with energy research being conducted at TUM and have contacts if I have questions about their research for my future projects.
3. I have a more broad knowledge of the energy sector worldwide, and can identify how the energy sector is not just influenced by local policies and events, but also worldwide policies and events.