

IGERT Summer in Munich 2011

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Table of Contents

Overview.....	3
ClimaDesign Course (5/16/11-5/20/11).....	3
Meetings with Benjamin Reuter, Automotive Engineering-TUM (5/18/11, 5/31/11).....	3
Meetings with Hammacher group, Electrical Engineering-TUM (5/24/11, 5/27/11, 6/29/11, 7/30/11 in Austin)	4
Drivers of Change Workshop, Oscar Von Miller Forum (5/24/11)	5
Meeting with BMW (5/25/11)	5
Meeting with Tomas Mezger, FFE (5/25/11).....	6
Presentation to Department of Architecture, TUM (5/26/11).....	8
Meeting with EON (5/26/11).....	8
Meeting with Infineon (5/30/11)	9
Attending TUM courses (6/1/11)	11
Meeting with SWM (6/1/11).....	11
Meeting with Siemens (6/6/11).....	12
Diesel Reloaded Presentation (6/7/11).....	12
IGSSE Conference, Raitenhaslach (6/8/11-6/10/11).....	13
Intersolar Convention (6/10/11)	13
Meeting with Desertec Initiative (6/15/11)	13
Meeting with Daimler, Stuttgart (6/15/11)	15
Fraunhofer Institute, Freiburg (6/16/11).....	16
Innovation Academy Tour, Freiburg (6/17/11).....	16
Trip to Geothermal Plant (6/27/11)	16
Presentation to Automotive Engineering Group (6/29/11)	18
The German Perspective.....	18
Exploring Munich and Germany.....	19

Overview

Students from the Sustainable Grid IGERT at the University of Texas at Austin were sent to Munich, Germany as part of a seven-week summer outreach internship starting May 2011. The internship had multiple goals, specifically being to foster relations between the University of Texas at Austin and the Technical University of Munich (TUM), to gain insight into the sustainable grid situation in Europe, to develop research ideas in an informal and new setting, and to qualitatively enrich the Ph.D. experience through cultural exchange.

The students were hosted by Professor Werner Lang of the Department of Architecture at TUM, and were assisted greatly by Konstanze Elbel, also of the Department of Architecture. The students lived in apartments near the city center for the duration of the trip and experienced a great deal of Bavarian culture in addition to their professional outings and meetings.

ClimaDesign Course (5/16/11-5/20/11)

The IGERT team took a weeklong course offered by the ClimaDesign program at TUM. The ClimaDesign program is a Master's level degree program offered at TUM focusing on sustainable design in architecture. The course, taught in a combination of English and German, exposed the IGERT students to various principles of sustainable design including energy-efficient facades and building flow modeling. Upon completion of the unit, the IGERT team joined the class on a trip to TUM's campus in Garching (northern Munich) to see the wind tunnel used by the department to perform experiments.

Meetings with Benjamin Reuter, Automotive Engineering-TUM (5/18/11, 5/31/11)

Given a number of the IGERT students' interest in automotive and electrified automotive technologies, Konstanze Elbel arranged for the IGERT students to meet with a PhD student whose research focus was automotive technologies (Benjamin Reuter). Benjamin's office was at the TUM Garching campus. In our first meeting, Dave Tuttle gave a presentation on his area of research (PEVs and the electric grid). This presentation fostered follow-on conversations about advancements in conventional powertrain efficiencies, analysis of plug-in vehicle implications to the grid and potential customer acceptance, and vehicle manufacturers efforts in charging station standards and PEV product development. Later in May, Benjamin gave a tour of the numerous automotive related labs at the TUM Garching Campus.

Meetings with Hammacher group, Electrical Engineering-TUM (5/24/11, 5/27/11, 6/29/11, 7/30/11 in Austin)

German Attendee(s):

Prof. Dr. rer. nat.

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The IGERT students met extensively with Professor Thomas Hammacher and his students throughout the duration of the trip. Professor Hammacher and his group, of TUM's electrical engineering department, work on a wide variety of engineering problems that the IGERT team found highly pertinent to their own individual research interests, as well as to broader IGERT and Pecan Street Project goals. Dr. Hamacher's work focuses on energy economy & application, thus he is heavily involved in smart grid technology, integration of electric vehicles, energy storage, etc. Some of his projects include, but are not limited to:

- Johannes focus is building simulation designs, using National Instrument's LabVIEW, compact-RIO, as well as a TRNSYS17 software.
- Matthias studying how all forms of energy production tie into a large network of energy loads, localized usage patterns, transmission networks, constraints, storage, etc. The end goal is to try to make sure all loads are met according to energy economies of scale.
- There is also some study in CO₂ cap & trade (i.e. buying CO₂ allowances) vs. an outright carbon tax.
- Economics of salt cavern storage of H₂ gas (vs. pumped hydro storage)
- Small, household CHP plants

In July, following the IGERT students' return from Munich, a team of students from Professor Hammacher's group attended the NI Week conference in Austin and had the opportunity to meet with a group organized by Professor Tom Edgar.

Drivers of Change Workshop, Oscar Von Miller Forum (5/24/11)

The IGERT students participated in a workshop focusing on the reconstruction of the city of Nuremburg, Germany. The workshop was comprised of upper division undergraduate architecture students who were tasked with the problem of revitalizing a city decimated by high unemployment, heavily polluted streets and few positive future prospects.

Students were broken up into several groups and put into stations. Each station had its own set of visual aids to help students prioritize the needs of Nuremburg (Ex: jobs, clean environment, ecosystem protection). The selection of prioritized needs that students made were saved as each group rotated between stations. At the end, the most important priorities were identified and put on a poster board. This facilitated class discussion for the best path to move forward for the revitalization and reconstruction of Nuremburg.

Meeting with BMW (5/25/11)

The IGERT students met with BMW in Munich (the headquarters for BMW). The representative had led BMW's electrification efforts while they were in the early, experimental phase. He indicated that the group was previously in a "skunk works" phase (similar to the secret Lockheed Skunk Works efforts) outside their mainstream R&D organization. BMW management had recently decided to transition their electric drive development efforts from a skunk-works-like hidden effort to their mainstream R&D organization with full funding, resources, and schedule for production. Their decision appeared to be driven from advancements and production of electric vehicles by competitors as well as BMW's own experience with its electric Mini-E prototype field tests, increasingly stringent emissions regulations, increasing concerns over long term oil supplies, and further advances in electrified powertrain technologies. The perceived viability of electric drive was also reinforced by the recent announcement by German Chancellor Angela Merkel's goal of 1M PEVs by 2020. It is doubtful that the Chancellor would have stated this goal without a clear signal from the German automakers on the viability of electric drive. As part of the electric drive transition to mainstream product development, BMW now has announced its new "i" strategic product line with its i3 BEV and i8 performance PHEV supercar.

Numerous PEV related topics were discussed. Charge coupling connector standards for Europe are years behind the U.S. (which has settled on the SAE J1772 connector). It appears to be more difficult to negotiate a single standard given the different electrical systems and national/corporate interests. Despite these challenges, the IEC/ISO standards are targeted to be settled before the i3 and i8 are available for sale by 2013-2014.

There was a difference of opinion on the use of PEVs for grid level demand response. One BMW opinion was that the batteries would only be used as a benefit for the grid in a “second life” application. This view ignored the opportunity of using variable charging in a way that was of benefit to the grid and within a charge/discharge rate, temperature and state of charge window which would not harm long term battery durability. Refusing to consider the PEV for DR applications also ignored the fact that the SAE J1772 standard already includes the sufficient supporting functions. Therefore, at the very least BMW PEVs destined for the US would likely support DR (whether BMW intends to or not) given they should be J1772 compliant.

The IGERT students toured the impressive BMW World pavilion where customers can view all the BMW models, arrange for European delivery of their new BMW, view engine cut-away displays, and learn the history of BMW.

Meeting with Tomas Mezger, FFE (5/25/11)

German Attendee(s):

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Perhaps the first, very productive meeting the IGERTs had where we found “our people”! FfE is a non-profit organization who’s structure seems to be analogous to a German version of NREL. The group we met with all were intimately involved with the development and testing of an electric vehicle – a Toyota Prius, retrofitted to an eREV with a charging station inside a small garage.

The meeting was conducted by Tomás Mezger, although the senior member of staff was Dr. Wolfgang Mauch. Tomás did most of the talking for FfE, as Dr. Mauch spoke little English, but perhaps comprehended more than he was able to convey.

The meeting started out discussing some facts regarding German Solar PV and rate structures. This was perhaps the first time the IGERTs learned of the German feed-in tariff, whereby solar PV customers were able to receive 0.27€/kW-hr on energy generated, yet consumption prices of electricity were around 0.22€/kW-hr. However, in some cases the PV rate structures were moving to where new customers would get paid based upon the amount of renewable energy they consume locally. This seems very complementary to electric vehicle proliferation, as one would actually get “paid” to fill up there vehicle (minus the initial capital investment of the solar PV array).

A few other items learned in our discussions:

- France is > 80% nuclear powered, and actually load-follow their energy production
- Germany also has lots of issues with trying to export energy generated in the North, down to States in the South. Known as “NIMBY” – Not In My Backyard!, Germany has even more difficulty for they must work with local States (16 in Germany?) on where to build and route transmission lines. Unfortunately, there seems to be no “governing agency” that can use the power of eminent domain to force the issue.
- There are about 80M people in Germany, with about 45M cars, total
- The German counterpart to <http://www.fueleconomy.gov/>, is <http://www.spritmonitor.de/en/> to help calculate a car’s fuel economy. However, the testing protocol are designed and mandated by a few key German automotive manufacturers. Thus, there is likely a bias!
- The average (3 person) German utility bill is about 180€/mo (x 1.46 \$/€) ≈ \$260/mo. Again, for a national average of about 0.22€/kW-hr, this means about 820 kW-hr consumed, per month, per household. Understanding the German price per kW-hr is 0.22€/kW-hr to an American National Average of about \$0.11/kW-hr, this means **Germans pay about 3x as much as Americans for the consumption of electricity**. Thus, the average German electric bill, converted to an American “basis”, is about \$87/mo. This is for an average, 3 person, 75-80m³ (2,600 – 2,800 ft³) home.
- Total annual electricity consumption is roughly 3,600 kW-hr per 3 person home. Or, about 1,200 kW-hr/year, per person.

- **1,200 kW-hr/yr * 0.22€/kW-hr * 1yr/12mo = 22€/mo, per person, not 60€ ?!**
- However, Germans also have utility bills in the form of heating (natural gas – methane), water, and waste. And, most of the energy savings realized in their country is off **heating**. Thus, it's best to use natural gas to heat a household and insulate it well.

The meeting was concluded with a short tour of their Toyota Prius, converted to an PHEV.

Presentation to Department of Architecture, TUM (5/26/11)

The IGERT team had the opportunity to present their research projects to members of Professor Lang's group in the architecture department. Attendees were given an overview on the Pecan Street Project as well, which many found to be intriguing, sparking in-depth discussion. The session was insightful to both attendees and the IGERT presenters, providing discussion on smart grid efforts in both Germany and Texas.

Meeting with EON (5/26/11)

EON is one of the major energy companies in Germany. The German energy market has been restructured so the EON representative was kind to provide background on the new structure, the roles of each of the participants, and some of the implications of the restructuring. Given this restructuring of the Germany energy market, EON had to divest its transmission and grid operations unit. The unit of EON that the IGERT students met with dealt with distribution below the 110kV level. The EON rep provided an informative presentation on their operations, renewable energy efforts, and challenges. This distribution unit of EON had 400,000km of <110kV distribution lines, and over 125,000 transformers. Given the attractive feed in tariffs, Bavaria alone has over 3500MW of PV on about 157,000 rooftops. New tariffs had been recently introduced which will encourage PV owners to use more of their own PV energy, perhaps to encourage investment in home energy storage, load shift, and/or limit the amount of rebates or costs to the government of the subsidies, and to reduce grid problems from huge amounts of distributed PV being fed back into the grid.

The precise details of the new tariff structure were not described, but the thrust was to strongly encourage homeowners to consume more than 30% of their own PV output. Given German homes have 3 phase service into their homes, the PV systems are tied to all 3 phases. An increasingly common problem for EON were installation problems which misbalanced the PV output across the 3 phases. Ideally, the output

should be perfectly balanced across all 3 phases. Additionally, there were concerns raised about the power quality (harmonics, for example) of the small scale PV power inverters from the panels onto the local distribution.

EON's focus on Smartgrid technologies was partially to manage power quality given the huge amount of distributed PV. Smartgrid technologies were of interest for VAR/Voltage support and maintaining power quality while avoiding additional capital investments in new wires or distribution. The idea of new, flexible additional load in the form of PEV charging was compelling to EON given the new tariff structure which encouraged a minimum premise usage of 30% of the PV output as well as the potential synergy between distributed generation, PV, and PEVs. Recognizing this opportunity, EON has a joint effort underway with Audi (perhaps part of Audi's "Balanced Mobility" effort". Interestingly, not only were the tariffs structured in a way to make PV attractive, from the recently restructured tariff, it appeared as though a homeowner with rooftop PV might be paid 7 euro-cents per kWh to charge their own PEV with their own PV output (instead of paying for conventional fuel or electricity).

Other interesting insights from EON: the average German uses only about 1200kWh per year per household of electricity. This is very low compared to the southwestern U.S. but note that this does not include the considerable energy that an average German consumes in heat from district heating, for example.

Meeting with Infineon (5/30/11)

German Attendee(s):

Herr Rainer Schmidt-Rudloff
Senior Manger
HR Talent Marketing
University Relations
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At Infineon, we met with Mr. Rudloff, who was a senior manager in charge of both HR Talent Marketing & University Relations. Thus, the context of the meeting seemed to be more geared on "selling Infineon" as a company, less technical in nature. In hindsight, perhaps it would have been more beneficial to meet with an actual project engineer at Infineon. Still, the meeting proved beneficial.

Infineon seems to focus primarily on IC manufacturing and power electronics (diodes, thyristors, IGBTs, etc.) Yet, these do play a key role into sustainability and renewable energy development as was discussed. Perhaps one of the key projects

Infineon is working on is long-distance transmission cables to export offshore wind back into Germany, as well as making use of the mountainous terrain of Norway for hydroelectric storage. It was noted that the medium of transportation for sea cabling was HVDC.

Another key role is in the electrification of railways and vehicles where power electronics converters, sensors, and microcontrollers are becoming more ubiquitous. Battery management, regenerative braking, range extension, and efficient well-to-wheel conversions are all key areas needing cutting-edge ICs. Naturally, smart grid technology parallels this development.

In discussions with both the e-Mobility & HVDC transmission cabling complementing North Sea wind production, we viewed two outstanding videos, which can be found here:

e-Mobility

http://www.infineon.com/cms/en/product/promopages/atv_movies/eMobility.html

North Sea – Wind Park

http://www.infineon.com/cms/en/product/promopages/IMM/Windenergy/video_eng.html

Other Links of Interest:

<http://www.infineon.com/cms/en/focus-areas/mobility/index.html>

<http://www.infineon.com/cms/en/focus-areas/index.html>

<http://www.infineon.com/cms/en/product/promopages/IMM/Windenergy/index.html>

DJSI – Dow Jones Sustainability Index

Aside: Infineon has a very large complex, and even a day care center right on the premise for families working at Infineon. You can drop off your children at work, facilitating both parents to work and even eliminating a daily errand. Parents know their children are safe, and they can even meet them for lunch. Cool concept.



Attending TUM courses (6/1/11)

The Technical University of Munich allows IGERT students to attend classes in various fields of study. Many classes are taught in English though students are also encouraged to sit in on German speaking classes, as math and science are universal languages. IGERT students attended classes including mathematics, physics and engineering. A wide spectrum of said classes is offered throughout the year. As of current, no credit is awarded for these classes.

Meeting with SWM (6/1/11)

SWM (Stadt Works Munich) is the utility for the Munich area. Interestingly, SWM is a progressive, municipally owned utility involved with PEVs and in many ways similar to Austin Energy. A subset of the IGERT students met with the SWM representative involved with their PEV programs. SWM's presentation covered a wide variety of topics over the course of the day-long meeting. SWM service 's areas, types of products (electricity, district heating, mass transit, for example), a number of the progressive programs that SWM was involved with (eg: geothermal for district heat + generation), the structure of their distribution grid and the power distribution within the average German home, and PEV related efforts were described. A tour of a representative ~500kVA distribution transformer in the nearby neighborhood was provided. From the description of their distribution grid, transformer architecture, and home wiring structure it is likely that Germans will enjoy relatively fast PEV charging from their standard outlet (about 3kW instead of a US NEMA 120V outlet of 1.3kW). The representative also indicated that with this 3kW charge rate there would likely be minimal concerns with PEV clustering in the distribution transformer network. The German grid, or at least SWM customers, appears to be able to deploy PEVs and enjoy the equivalent of U.S. Level 2 AC fast charging without the cost of a dedicated Level 2 EVSE in the U.S.

SWM had been involved with PEV pilot programs (such as the fleet of 26 BMW Mini-E's) and engaged with vehicle manufacturers. One of the interesting interactions described was the description to a German vehicle manufacturer of the implications of attempting to provide the same energy equivalent refueling rate as gasoline/diesel on an unadjusted basis (while 1 gallon is about 33kWh of energy, an electric motor is about 3x more efficient than a gas/diesel engine, for example). The vehicle manufacturer's engineers were shocked to learn about the need for an entire substation for one equivalent electric gas pump that could provide equivalent energy flow to a conventional gasoline pump. The discussion centered on how the PEV refueling paradigm is fundamentally different than a conventionally fueled vehicle. With a gasoline/diesel vehicle, an owner drives their vehicle to a refueling station on a regular basis to a refueling station that they don't really want to spend time at. Fortunately, they may only have to spend about 15-30 minutes to drive to

the gas station and refuel. We agreed that the key paradigm that must be appreciated is that with PEVs, one has their own “Personal Refueling Station” in their home and a PEV owner instead refuels “where they would typically be” instead of at a location “that they otherwise would not be visiting, nor want to be spending much time at”. Therefore, recharging at a slower rate at night where the vehicle is parked for 10-12 hours is typically not a problem. But we agreed, it was sometimes a challenge for automotive engineers or managers who have deeply ingrained views and experiences with the existing hydrocarbon based paradigm to immediately internalize the differences and advantages of electric refueling.

We were also fortunate enough to be given the opportunity to drive a Mini-E electric prototype that SWM had in its fleet for testing. We were also given a tour of their public charging station installation.

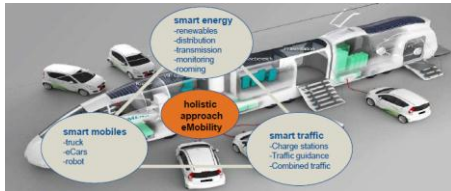
Meeting with Siemens (6/6/11)

Siemens is a large, established, and successful global firm involved with most, if not nearly all, aspects of electricity generation, transmission, and distribution. In addition, they have a successful business providing vehicle manufacturers (mainly German) electronic components or assemblies. The IGERT students met with representatives of the division which is involved with EVSE to PEV charging and communications. The particular Siemen representatives were deeply involved in the IEC/ISO PEV and EVSE standards activities as well as the development of the charging related electronic assemblies which would eventually be incorporated in a PEV itself. Siemens indicated that they were involved with multiple PEV pilot programs. We were shown an electric RUF Porsche that was used for their experiments. One of the key accomplishments that the Siemens representative believed needed to be completed quickly was the closure of the IEC/ISO 62196 spec for the charge coupler across Europe as well as the PLC (Power Line Communications) definition and protocol between the EVSE and the PEV. Asked why an integrated OnStar/CarWings-like embedded cell phone communications link wouldn't be sufficient, the reply was that in European parking garages the cell phone reception is sometimes poor and that this PLC capability would provide reliable and secure communication for charging billing for home as well as roaming. Interestingly, this Siemens representative voiced strong reservations of using PEVs for grid demand response by varying the charge rate.

Diesel Reloaded Presentation (6/7/11)

Diesel Reloaded was the name of the presentation which described the a multifaceted Siemens sponsored “Project Innotruck” which involves building a highly aerodynamic semi-tractor truck which is fully “drive by wire”. The

innovative shape is reminiscent of the Concorde supersonic jet. The Innotruck prototype was to show a holistic approach to eMobility with eCars connected to the smart home and SmartGrid infrastructure, demonstrate energy efficient powertrains, and integrate future automotive technologies (such as hybrid powertrains, drive by wire, system architecture, an onboard micro-smart grid, and human-machine interfaces).



IGSSE Conference, Raitenhaslach (6/8/11-6/10/11)

The IGERT team attended the International Graduate School of Science and Engineering Conference at the Raitenhaslach Monastery in Burghausen, Germany. The three-day retreat showcased the research projects of science and engineering graduate students at TUM. During the conference, the IGERT students met with professors, students, and various other research personnel at TUM. The IGERT students also attended workshops organized at the conference, based on topics such as science journalism and communicating scientific research with the public.

Intersolar Convention (6/10/11)

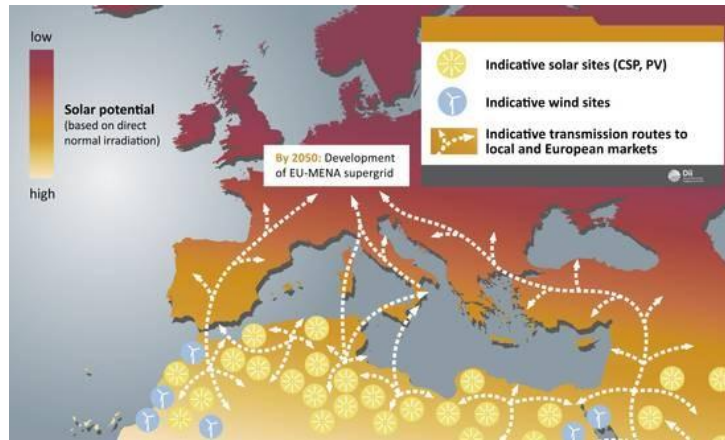
Following the IGSSE Conference, the team took a day trip to visit the Intersolar Convention near Munich, the largest solar trade fair. Apart from being exposed to many exciting solar technologies, the team got the opportunity to interface with many firms and professionals and discuss research and ideas.

Meeting with Desertec Initiative (6/15/11)

German Attendee(s):

Dr. Florian Zickfeld
Strategy Manager Generation
Schott Solar
zickfeld@dii-eumena.com

Frank Lenzen
Technology Associate –
lenzen@dii-eumena.com



Desertec is not a construction company; they are only a facilitator. Their job is to try to get parties to work together, to establish a timeline and break ground on a project site in North Africa. Then, they move onto the next project.

The concept of Desertec is harnessing the power of the sun in the sparse desert regions of North Africa and exporting this power back into the European Grid. Thus, clearly the Germans and EU is stressing renewable energy generation over energy independence. One of the biggest challenges is clearly the lack of transmission lines, as one has to drop cables on the floor of the Mediterranean or route power eastward, towards Egypt, then up into the EU from the southeast corner. Seems rather daunting.

Organization structure

Dii is comprised of about 30 people, with less than 10 being technical experts. They are an enabler to create markets founded by Schott Solar, Siemens, etc. They work with politicians, CEOs, etc. to make projects happen.

Currently, the EU grid is about 15% supplied by renewable energy (200-300 GW). As always, a struggle is the lack of interconnects. The goal of Dii is to incorporate North Africa into the EU grid, making one "supergrid". A very aggressive goal is to have the EU grid supplied by 80% renewable energy by 2050! Therefore, smart grid technology is essential.

Perhaps the biggest challenge in pushing Desertec is of a political nature, even between EU nations.

Companies Involved

- First Solar
- Schott Solar – 3 branches:
 - o CSP receiver tube – 70% market share (Ashemeda (sp?) = competitor)
 - o solar PV modules – thin film
 - o solar PV modules – poly crystalline, fully integrated (Albuquerque, NM)
- SMA Inverters

Links of Interest:

U.S. DoE Sunshot program

<http://www1.eere.energy.gov/solar/sunshot/>

Desertec Non-Profit organization

<http://www.desertec.org>

Meeting with Daimler, Stuttgart (6/15/11)

Two of the IGERT students met with an expert within Daimler (the manufacturer of Mercedes and Smart vehicles) in electric vehicle communications and control with the grid. Daimler provided an overview of their alternative fuel R&D efforts (which include Hydrogen fuel cell vehicles and PEVs) as well as a more detailed description of their PEV related efforts. Multiple pilots have been created with the Smart ED (Electric Drive), the A-class E-Cell, and A-Class E-Cell plus PHEV. Daimler is also deeply involved with the key IEC/ISO and SAE standards activities which are essential to make common the charging coupler for the various regions and the key EVSE-PEV communications to enable PEV intelligent charging.

A clear opinion emerged from Daimler (which was consistent with the other German organizations that we had visited) with respect to the ChaDeMo DC quick charging standard. The Europeans believed they had a clean sheet of paper given there are virtually no PEVs on the roads today and they were not going to accept what they perceived to be a suboptimal and more costly ChaDeMo DC quick charging standard simply because Nissan and Mitsubishi had recently introduced a relatively small number of electrified vehicles with these ChaDeMo quick charging ports and a few hundred of these ChaDeMo chargers were installed in Japan. The preferred solution is the IEC/ISO 62196 "Combo" connector and not ChaDeMo. Power Line Communications (PLC) between the EVSE and PEV were considered essential and valuable. Efforts were deployed to finalize the PLC standard within IEC/ISO which would be common with the SAE standard. This likely will be GreenPhy. Thus, even if the plastic connector physical attributes were different, the important signaling and protocol standards would be similar.



Fraunhofer Institute, Freiburg (6/16/11)

The IGERT students took a trip to Freiburg, Germany, home of the Vauban sustainable model city district as well as the Fraunhofer Institute of Solar Energy Systems (ISE). The Fraunhofer ISE is a research institution affiliated with the larger Fraunhofer organization that specializes in application-oriented research and is the largest such entity in Europe, with presences around the world. IGERT students met with researchers to discuss their projects, after which the group went to dinner with a researcher to further discuss.

Innovation Academy Tour, Freiburg (6/17/11)

The group took a tour of Vauban, Freiburg's sustainable model city district on the second day of their Freiburg trip. The group visited the Heliotrope, which is a 360° revolving house designed to optimize solar irradiation according to the seasons. The group also took a tour through sections of the district containing net-zero energy usage homes through the use of photovoltaics.

Trip to Geothermal Plant (6/27/11)

German Attendee(s):

Konstanze Elbel

German tour guide – grad student



The Unterhaching was the first geothermal power station in South Germany. It makes use of the Kalina system (~11% water, 89% ammonia) as the working fluid (boiling temperature of mixture is 50°C). It was initially planned for electricity generation, but the main focus shifted to district heating since, after 18 months, due

to a hotter than expected water supply and volume. This power plant could provide for 25% of the local heating requirements.

Unterhaching is tapping into the Molasse Basin of South Germany, which has ground water at temperatures between 85-140°C at depths from 1,500 – 5,000 meters. A second region favorable to geothermal energy is the Upper Rhine Rift, in southwest Germany, near the border with France. Geological analysis was conducted by the German Federal Ministry for the Environment (BMU).

Specifically, Unterhaching has 2 bore holes, a production well at 3,446m / 122°C, and an injection well at 3,864m / 133°C within porous limestone and dolomite inside the aquifer. *(It was briefly considered to swap the production & injection well directions due to the hotter observed temperatures, but costs and project layout was already under construction.)*

To prevent salt deposits, CO₂ outgassing, and/or corrosion of the piping network, the groundwater is pressurized with nitrogen to 8 bar, and the pipe walls are made of fiberglass reinforced plastic. Reinjection pressure is 6.5 bar.

Specifications

- Project cost was €80M
- Annual CO₂ savings of 35,000 tons
- Fluid output expected (120 L/s), received 150 L/s! (4.7B L of water use, annually)
- District Heating: 30.4 MW, up to 35MW (~3,000 households)
 - Houses are charged an initial connection fee of €1,234
 - Annual heating bill is approximately €2,106 for a single family home
- Electricity Generation: 3.4 MW (~6,000 households)
- Plant is used for district heating primarily, and any leftover heat is then used for electricity generation. Volumetric flow is kept constant. So, as heat load demand changes (up/down), so does electricity production (down/up).
- Cost amortization is expected in roughly 15 years
- First bore hole is 11¾" down to 1,000m, second bore is 8"
- Only 1 pump is needed, as the natural pressure pushes groundwater up to 170m of the surface
- Backup is 2 boilers (oil & gas), with a heating capacity of 2.3 MW
- Project scope is to double plant size, to service 50% of the heat load of the community (70 MW)
- Kalina system (ammonia / water mixture) is naturally, closed-loop
- Generator runs at 1,500 rpm, while the turbine runs at 13,800 rpm. It's coupled by a gearbox / transmission who's fluid is circulated & cooled. The turbine is constructed of titanium to keep it strong & lightweight.
- Max electrical generator cost paid by Stadtwerkes Munchen (SW//M), which give incentives to small power plants (distributed generation)

- An advantage of geothermal power plant production is they are small, and clean. So, they can be placed in the public's "backyard". No NIMBY protestors!
- Across Germany, there are currently 4 geothermal plants with CHP/Elec Generation using the Kalina system

Some basic geothermal information

- Temp of Earth's mantle: 1,000 °C
- Temp of Earth's core: 5,000 °C
- Heat created due to the disintegration of uranium

Presentation to Automotive Engineering Group (6/29/11)

One of the IGERT students (Dave Tuttle) gave a presentation at the TUM Garching campus to a group of students and professors involved in a variety of PEV related technologies. The presentation provided a background on the motivation for PEV-Grid related research, the potential benefits of the synergy between PEVs and the electricity grid, and a number of areas of promising PEV related research for them to contemplate.

The German Perspective

After interacting with various German students, researchers, and professionals, a few key insights were developed from the IGERT student group.

- Germans in the academic/professional space are more or less pessimistic about using nuclear sources for energy generation, and this sentiment is expressed to an even greater extent in the German public. Germany plans to be nuclear-free by 2022.
- In contrast to the largely American notion of wanting to maximize domestic production/consumption of energy, the Germans seem to be more open to importing energy and being more reliant on foreign sources.
- Solar is everywhere. On any given train ride through the countryside, the first thing one notices is the extremely high concentration of rooftop PV. Generous feed-in-tariffs help promote their proliferation, although they are soon to be phased out.
- Residents are able to choose a higher electricity tariff (domestically) that guarantees that their energy comes from renewable sources, and this option is very popular.

Exploring Munich and Germany

Munich is a beautiful city with stunning architecture, classical narrow winding streets and numerous large recreational parks. TUM faculty loaned IGERT students bicycles as a means of transportation and as way to explore the city. Munich is a cyclist's town. Every major street has a bike path that allows cyclists to safely maneuver the city. With the addition of a great public transportation system that includes buses and an underground metro, students can explore any part of Munich without a car.

Munich has a plethora of great art, culture and history. Near TUM there are four art museums that feature works ranging from pre-Renaissance to modern art. Or one can grab a game of chess with life-sized pieces at a Munich chess park. For a more solemn experience one can visit the Dachau concentration camp memorial in the north of the city. Munich is also famous for its grand Biergartens, where IGERT students enjoyed the occasional pint and pretzel, a famously Bavarian pairing. IGERT students also took weekend bike trips through the Bavarian country-side, stopping in at various inns and restaurants for a comprehensive cultural experience.