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IGERT 2011 Exchange at the Technical University Munich

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Background

- **NSF-IGERT Fellowship Description (C.9. – International Collaboration)**
  - *"Because IGERT internships are meant to improve the research experience of trainees through catalysis of new ideas, access to specialized research facilities, and development of professional relationships, our international collaboration with ITESM (Monterrey Tech in Monterrey, Mexico) will be a central part of the educational experience of many IGERT trainees."*
- **Dr. Werner Lang** – faculty participant of NSF-IGERT Fellowship grant
  - part of both the Fellowship Executive Committee & Research Committee
  - Dr. Lang was returning to Munich, Germany to accept a position in the TUM School of Architecture
  - Idea was suggested to do the International Collaboration with Technische Universität München (TUM) in lieu of Monterrey, Mexico
  - students were welcome to work out of Dr. Lang's TUM Architecture department & even attend classes in Clima Design (MS program) for the 1st week, until adjusted. Additional support given in the form of Konstanze Elbel, part of Dr. Werner Lang's architecture staff

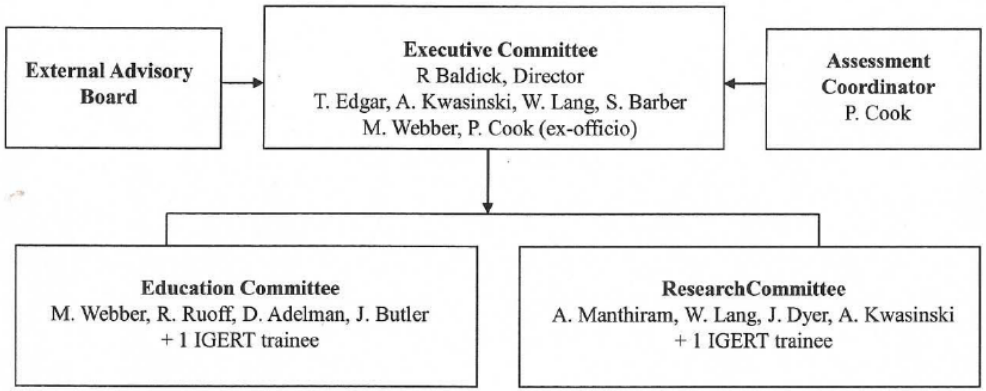

Figure 2. Management Structure for IGERT Project

Structure

- Structure of International Study Program to Munich
  - only **NSF-IGERT Trainees** *(fully funded)* had this opportunity *(not IGERT Affiliates)*
  - **4 of the 5** IGERT Trainees were able to attend:

    (Dave Tuttle, Hunter Estes, Akshay Sriprasad, Greg Dahlberg) Sorry, Matt!
  - students were to fly out to Munich for roughly **6 weeks**, based upon their course & finals schedules. Start date was essentially Monday, May 16th 2011 for this was the start of the 1 week/month **ClimaDesign** MS course schedule

    (Module 9: Ventilation – simulation tools and calculation methods, building aerodynamics, air-flow simulation, wind tunnel, model construction and simulation, fluid-mechanical processes) – *air flow in & around building designs*
  - **Accommodations**: 4 Students were lodged in two, 2 bedroom, 1 bath "flats", within walking distance of the U6 German U-bahn public transit system. Additionally,
    - Monthly U/S-Bahn passes also allow access to buses,
    - TUM worked to supply us with bicycles to help with transit,
    - TUM allowed full access to their libraries & wireless Internet while on campus,
    - Off campus, students had Vodafone wireless Internet aircards, &
    - All students had "handys" (cell phones) for communication

Structure *(cont.)*

- **First week** of the program was to get **acclimated** to Germany, along with Academic study as part of ClimaDesign.
- From there, **meetings w/ Industry & Academia** were scheduled based upon student's interest. Additionally, other larger events planned were:
  - International Graduate School of Science & Engineering (IGSSE) at The Monastry Raitenhaslach in Berghausen, Germany
  - Intersolar München
  - Freiburg im Breisgau visit & tour
    - Fraunhofer Institute for Solar Energy Systems (ISE)
    - The Sustainable District (Vauban)
- Students were also **encouraged to present their research** to the TUM Architecture Department & Academic community
- Program was **flexible** so if student's desires gravitated them in a particular direction, Konstanze Elbel helped to arrange meetings, events, reservations, translate, etc.
  - Dave Tuttle – EVs, pHEVs, charging times/rates & grid management
  - Akshay Sriprasad – Smart Grid & Pecan Street related projects w/ Dr. Hamacher & Johannes
  - Hunter Estes – Desertec & Geothermal Plant - Unterhaching
  - Greg Dahlberg – Power Electronics w/ Dr. Ralph Kennel

Goals of Program

- **Educational enrichment**
- Unique ability to **engage Industry** officials in a foreign, pro-renewable energy country like Germany
- In terms of solar PV installs & wind generation, Germany is ahead of the U.S. So this allows one to **learn the mistakes of the first-to-act**, hopefully expediting successful deployment back in the U.S.
- 6 week timeframe allows one to no longer think as a visitor, but instead, become immersed in the flow & mindset of a foreign culture. **Facilitates thinking outside-of-the-box**, or helps to **challenge the U.S. norm**
- Compare notes (U.S. versus Germany) & try to choose the "**best of both Worlds**"
- Potential **research collaboration** opportunities
- Promotes healthy **collegiate alliance** between UT Austin & TUM

Some Lessons Learned

- Germany **Feed-In Tariff** structure vs. Tax Credit (U.S.) to help w/ proliferation of solar PV. But…what now is the next step?!
- Germany adopting renewable energy initiatives as part of their **Constitution**
- **Public sentiments** change rapidly (Fukushima → close German nuclear plants!)
- 16 States of Germany & **issues with building transmission** lines (NIMBY, NOPE, etc.)

  No power of eminent domain!
- Cost of electricity in Germany is **3x the cost in the U.S.** But, load **demand is much less** & primarily due to **heating** which can be supplied directly via district heating. Most places make use of natural lighting & don't have dryers. As such, overall electric bills are much less (in terms of usage) than U.S.
- Germany has strong renewable energy drive, yet **not the same fierce energy independence** that the United States has?!
  - Natural Gas pipeline connection to Russia
  - closing of Nuclear plants & willingness to import power from France
  - Desertec (North Africa solar thermal & solar PV systems)
  - "Grid" focus is whole E.U. grid, not just German *(i.e. pumped hydro storage in Norway)*
- Germans love their sportscars & don't seem to have the same willingness to embrace EVs. (As such, the big German auto manufacturers are behind the curve!) German's automotive energy focus is on clean diesel & H2.

Long-Term Collaboration?

Dr. Thomas Hamacher (EE)

- Dr. Hamacher's research group seems to be perhaps the **best fit** to the UT Austin, NSF-IGERTs. His area focuses on **energy economy & application**, thus he is heavily involved in **smart grid** technology, integration of **electric vehicles**, **mobility, 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 CO_2 cap & trade (i.e. buying CO_2 allowances) vs. an outright carbon tax.
  - Economics of salt cavern storage of H_2 gas (vs. pumped hydro storage)
  - small, household CHP plants
  - building demand response & rate structures
- Johannes has visited UT Austin already as part of NI Week
- Dr. Hamacher is looking to arrange a visit w/ Dr. Edgar & the NSF-IGERTs in the near future

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IGERT Munich Activities & Report

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

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

- 1 week class on the various principles of sustainable design including energy-efficient facades & building flow modeling
- Tour of Garching TUM campus wind tunnels

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

- UT presentation on PEV-Grid research
- Discussions on advanced powertrain technologies, PEV synergies with the grid, key industry standards development, TUM project BEV
- Follow-up tours of automotive lab, combustion lab, and other labs at TUM Garching

Hammacher group, Elect Eng-TUM (5/24/11, 5/27/11, 6/29/11, 7/30/11 in Austin)

- Presentation by TUM of building energy management system using National Instrument's LabVIEW, compact-RIO, as well as a TRNSYS17 software
- TUM presentation of 2030/2050 Energy system vision (including salt cavern H2 storage)

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

- Day Long "Visioning" exercise with the topic: the best path to move forward for the revitalization and reconstruction of an old section of Nuremburg

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BMW Munich, electric vehicle development

- Presentation by BMW leader of “skunk works” plug-in vehicle development
- Roadmap: MiniE-> “i3” BEV and “i8” PHEV supercar
- Discussions on battery trends, PEV-Grid interactions (V2G, intelligent charging..etc)
- Chancellor Merkel: 1M PEVs on German roads by 2020
- Tour of BMW World


Tomas Mezger, FFE (5/25/11), a spinoff of TUM

- UT presentation on PEV-Grid research
- Discussions on FFE’s Prius PHEV conversion, German Solar PV and rate structures.
- 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, opportunity to be paid to charge a German PEV

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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
- Discussions on Smartgrid, PEVs and the Grid, Pecan Street Consortium in Austin

Meeting with EON (5/26/11)

- EON is one of the major energy companies in Germany (now distribution/retail)
- Discussions on German PV challenges
- Concerns raised about the power quality (harmonics, for example) of the small scale PV power inverters from the panels onto the local distribution.
- Smartgrid of interest for VAR/Voltage support and maintaining power quality given huge amount of rooftop PV while avoiding additional capital investments
- Flexible 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.
- EON has a joint effort underway with Audi (likely part of Audi's "Balanced Mobility" effort")

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Meeting with Infineon (5/30/11)

- Infineon presentation of their power electronics converters, sensors, and microcontrollers
- Discussions of Infineon technologies incorporated with both e-Mobility & HVDC transmission cabling complementing North Sea wind production
- Interesting to note the work environment: On-site day care, windows

Attending TUM courses (6/1/11)

- Many classes are taught in English, German speaking classes also open (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.

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Meeting with SWM (6/1/11): Stadt Works Munich, the Munich Utility

- SWM is a progressive, municipally owned utility involved w/PEVs & renewables
- SWM presentations on geothermal for district heat + generation, the structure of their distribution grid, their power distribution design, and PEV related efforts
- Tour of a representative ~500kVA distribution transformer in the nearby neighborhood
- Their distribution grid, transformer architecture, and home wiring structure is likely to support 3kW without any concerns over PEV clustering.
- Test drive of Mini-E

Meeting with Siemens (6/6/11)

- Met with representatives involved with EVSE to PEV charging and communications.
- 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 presentations on multiple PEV pilot programs & related technologies.
- Shown an electric RUF Porsche that was used for their experiments.
- Focus & concern: closure of the IEC/ISO 62196 spec for the charge coupler across Europe and the PLC (Power Line Communications) definition and protocol between the EVSE and the PEV.

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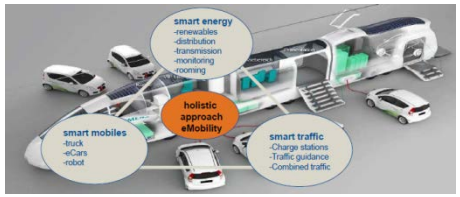
"Diesel Reloaded" Presentation (6/7/11)

- Presentation of multifaceted Siemens sponsored "Project Innotruck" which involves building a highly aerodynamic semi-tractor truck which is fully "drive by wire".
- 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).



International Graduate School of Science and Engineering (IGSSE) Conference, Raitenhaslach (6/8/11-6/10/11)

- Three-day retreat showcased the research projects graduate students at TUM.
- IGERT students met with professors, students from TUM.
- Workshops organized at the conference, based on topics such as science journalism and communicating scientific research with the public

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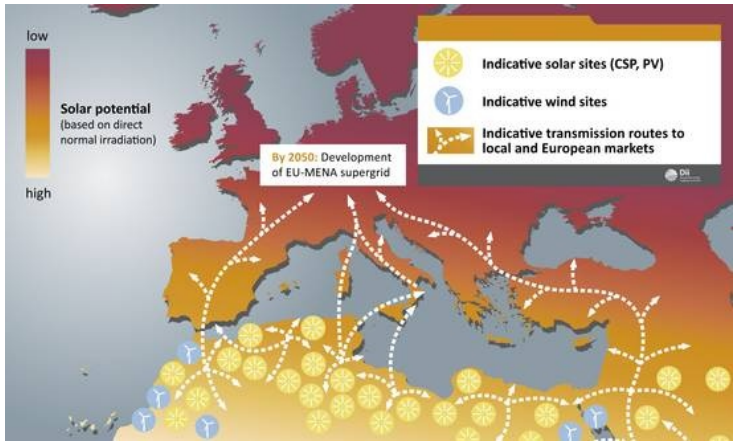
Intersolar Convention (6/10/11)

- Intersolar Convention in Munich, the largest solar trade fair in the world
- Exposed to many exciting solar technologies, interfaced with many firms and professionals and discussed research and ideas.

Meeting with Desertec Initiative (6/15/11)

- Desertec concept is harnessing the power of the sun in the sparse desert regions of North Africa and exporting this power back into the European Grid.
- Challenge of transmission lines, cables on the floor of the Mediterranean or route power eastward, towards Egypt, then up into the EU from the southeast corner.



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

- Presentation by Daimler senior technical staff involved with electric vehicle communications and control with the grid.
- Overview of their Daimler 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.
- Discussions on key IEC/ISO and SAE standards activities essential to make common the charging coupler for the various regions and the key EVSE-PEV communications to enable PEV intelligent charging

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Fraunhofer Institute, Freiburg (6/16/11)

- Fraunhofer Institute of Solar Energy Systems (ISE) a research institution affiliated with the larger Fraunhofer organization that specializes in application-oriented research
- Presentation of Fraunhofer research projects, structure, funding (Gov & MP3 royalties)
- Variety of discussions of Fraunhofer projects, PV, PV validation, PEVs, PEVs and the Grid

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

- Tour of Vauban, Freiburg's sustainable model city district
- Visited the Heliotrope, a 360° revolving house to optimize solar irradiation harvest
- Tour through sections of the district containing net-zero energy usage homes through the use of photovoltaics

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Trip to Unterhaching Geothermal Plant (6/27/11)

- the first geothermal power station in South Germany, provides for 25% of local heating ts.
- Unterhaching taps into the Molasse Basin of South Germany, with ground water at temperatures between 85-140ºC at depths from 1,500 – 5,000 meters.
- 2 bore holes, a production well at 3,446m / 122ºC, and an injection well at 3,864m / 133ºC within porous limestone and dolomite inside the aquifer

Specifications

- Project cost was €80M
- Annual CO_2 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.

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Presentation to Computer Science Group (6/29/11)

- Presentation at the TUM Garching campus to students and professors involved in a variety of PEV related technologies.
- 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.

Some interesting German Perspectives

- Arrived after Fukushima: German protests of Nuclear power.
- Pessimistic about using nuclear sources for energy generation, Germany plans to be nuclear-free by 2022
- In contrast to the largely American notion of wanting to maximize domestic production to create "energy independence: the Germans seem to be more open to importing energy and being more reliant on foreign sources.
- Solar PV 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 Feed-In Tariffs are becoming less attractive
- 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.

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Exploring Munich and Germany

- Munich is a beautiful city with stunning architecture, classical narrow winding streets, numerous large recreational parks, biergartens, and a plethora of great art, culture and history
- Bicycles are a great means of transportation and as way to explore the city
- Great public transportation system that includes buses and an underground metro, students can explore any part of Munich without a car.
- Near TUM there are four art museums that feature works ranging from pre-Renaissance to modern art.
- One can grab a game of chess with life-sized pieces at a Munich chess park.
- Solemn experience: Dachau concentration camp memorial
- Weekend bike trips through the Bavarian country-side, stopping in at various inns and restaurants