Renewable Systems Interconnection

Juan J. Torres
Manager, Energy Systems Analysis
Sandia National Laboratories

jjtorre@sandia.gov

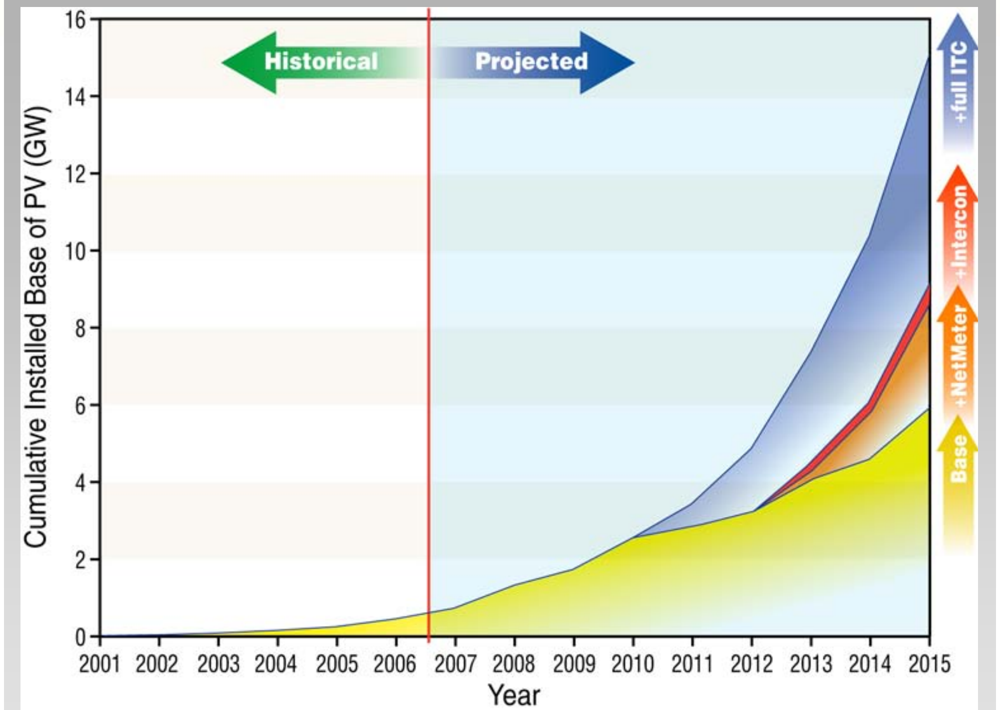
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Significant growth projected for Distributed PV Integration

Driving the market:

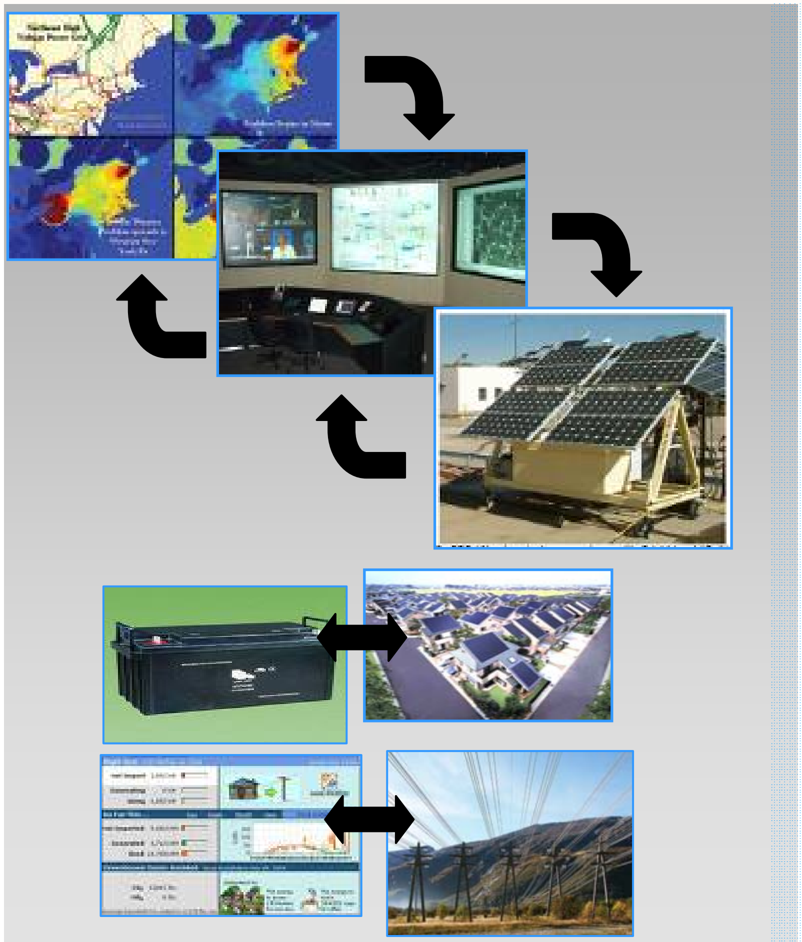
- **Climate change**
- **Cost reductions**

Market Risk: As PV production approaches ~5% of installed generating capacity, grid impacts could create barriers to future growth.



Grid-Connected Distributed PV Growth, 2001–2006 Projected to 2015

RSI Study: Removing barriers and reduce risks

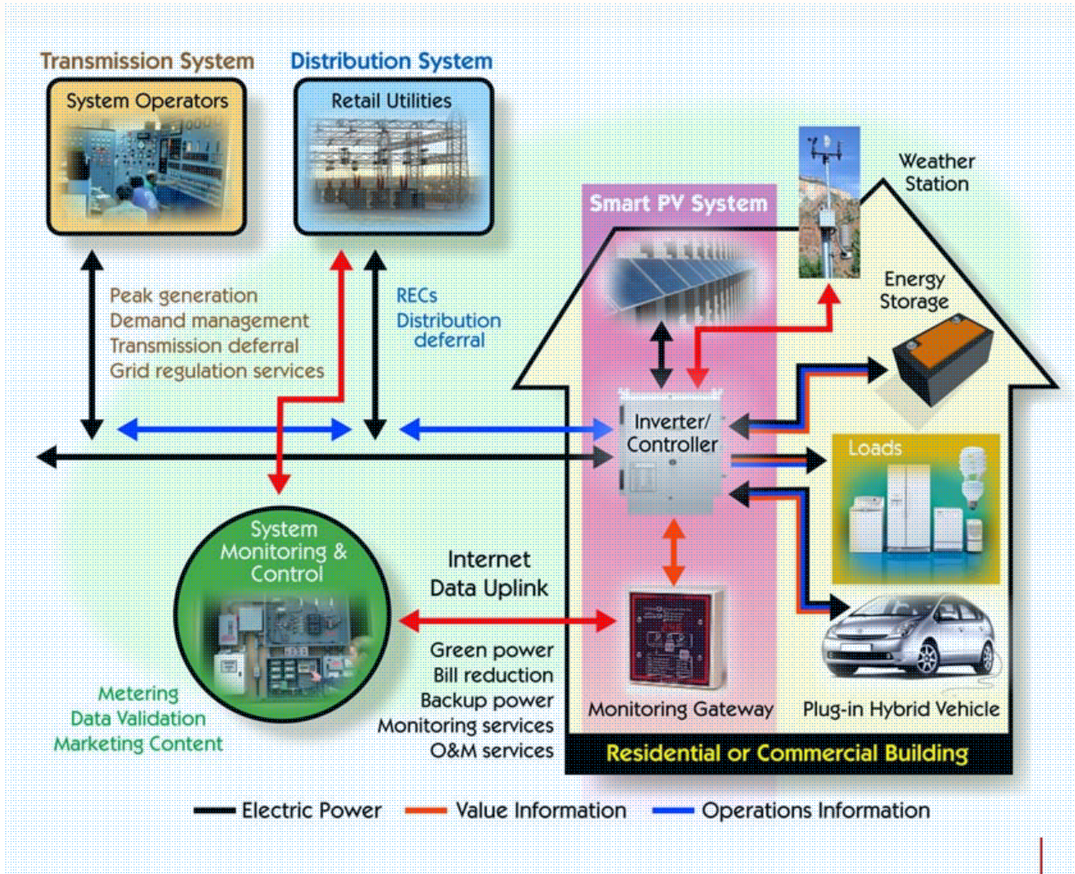


1. Distributed PV System Technology Development
2. Advanced Distribution Systems
3. System Level Test and Demonstration
4. Distributed Renewable Energy System Analysis
5. Solar Resource Assessment
6. Codes, Standards, and Regulatory Implementation

14 reports in six areas

Objectives for Distributed PV System Technology Development

- Solar Energy Grid Integration Systems (SEGIS) – Integrated energy management, control and communication.
- More reliable inverter/controller.
- Embedded voltage regulation.
- Investigate new DC power distribution architectures.
- Secure/robust communications protocols.
- Inverter-tied storage systems to allow intentional islanding (micrograids) and system optimization (demand control).
- Energy system controllers to monitor solar resource, utility pricing, building loads and occupant data.



The Solar Energy Grid Integration System (SEGIS) integrated with Advanced Distribution Systems

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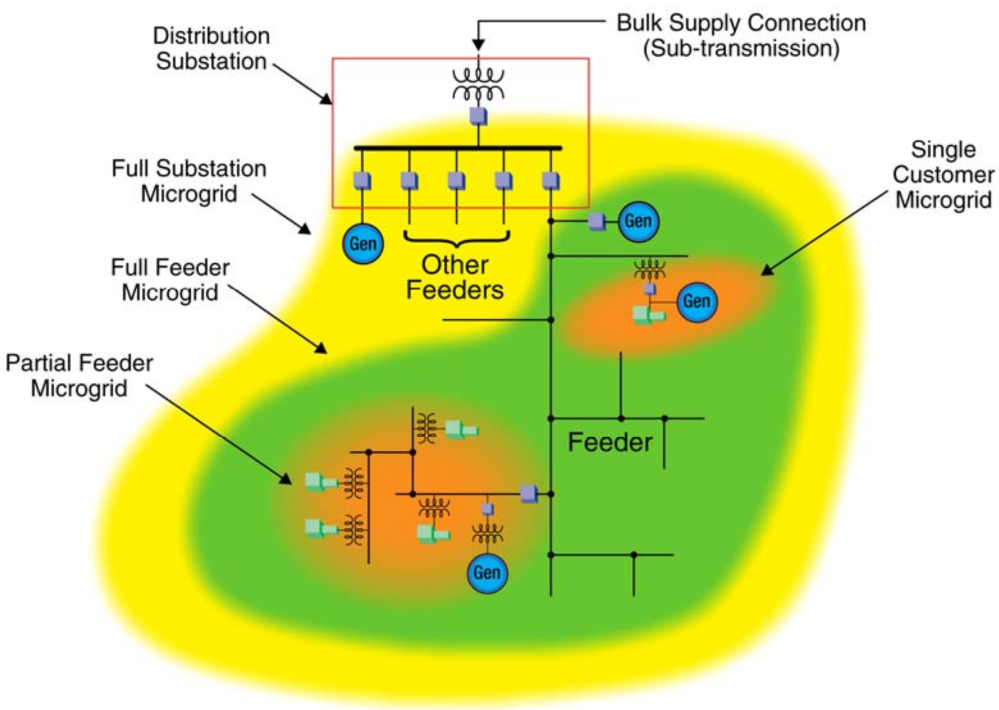
Objectives for Advanced Distribution Systems

- Increased automation.
- Emphasize ***"market-driven response"***
- PV-friendly distribution systems.
- Multi-scale microgrid technologies.



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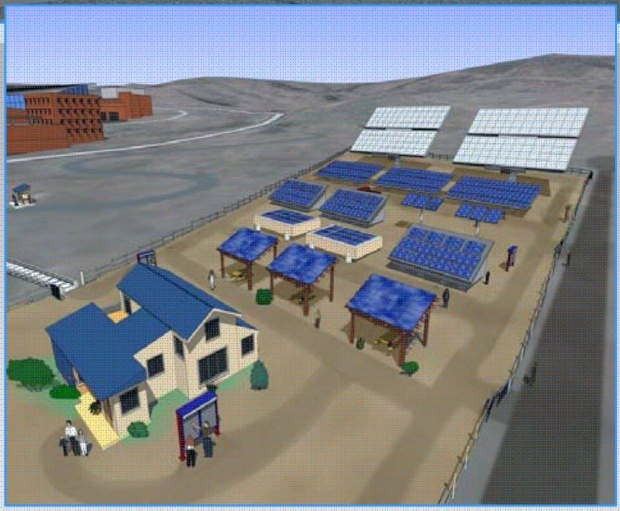
Objectives for System Level Test and Demonstrations

Laboratory Based Testing

- Models for specific PV system equipment, especially inverter performance.
- Laboratory capabilities for testing high penetration scenarios.
- Establish test protocols for emerging communication methods.
- Evaluate control schemes for autonomous VAr compensation under conditions of multiple inverters.



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Objectives for System Level Test and Demonstrations

Field Testing and Demonstrations

- Test voltage regulation support, frequency regulation support, spinning reserve, customer peak load reduction.
- Test integration of energy management systems with PV and storage.
- Evaluate impact of high PV penetration on distribution.
- Investigate voltage impacts, SEGIS effectiveness, faults, fuses.
- Investigate PV installed in sub-optimal situations.

Premier Gardens Subdivision, Rancho Cordova, CA

Source: Sacramento Municipal Utility District

15 MW PV Installation, Nellis Air Force Base, NV

Source: SunPower Corporation

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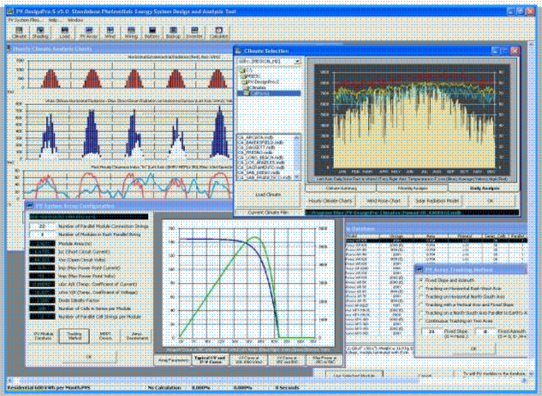
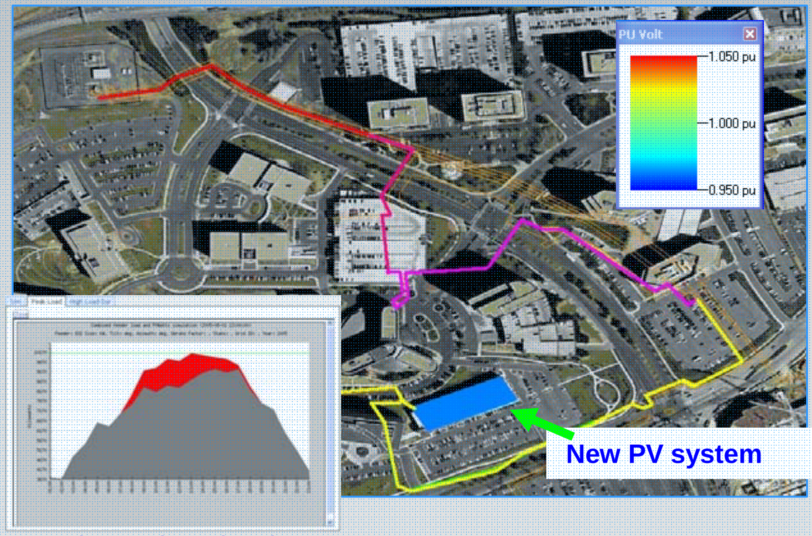
Objectives for Distributed Renewable Energy System Analysis

Technical Analysis

- Solve ground fault over-voltage on sub-transmission.
- Adapt distribution system protective systems to handle PV.
- Develop new voltage regulation schemes.
- Solve PV grounding compatibility problem.
- Create benchmark cases for testing models and software.
- Develop automated tools to evaluate impact of PV on distribution.
- Update commercial load flow and fault current calculation software for multiple distributed energy sources.



Improving voltage profile of distribution feeder with PV



Peak Load Reduction

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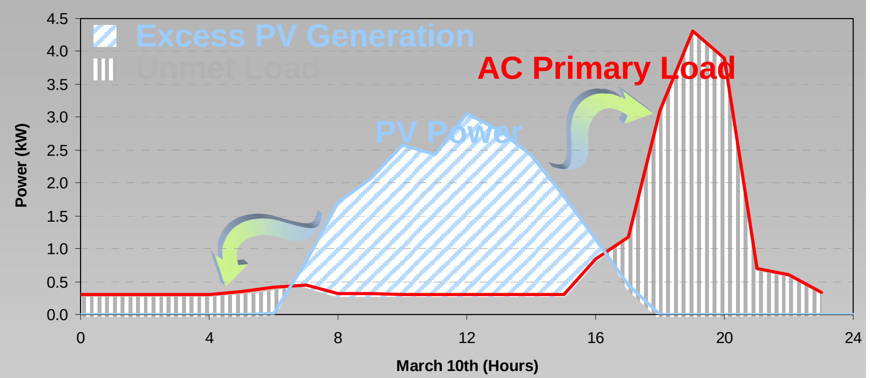
Objectives for Distributed Renewable Energy System Analysis

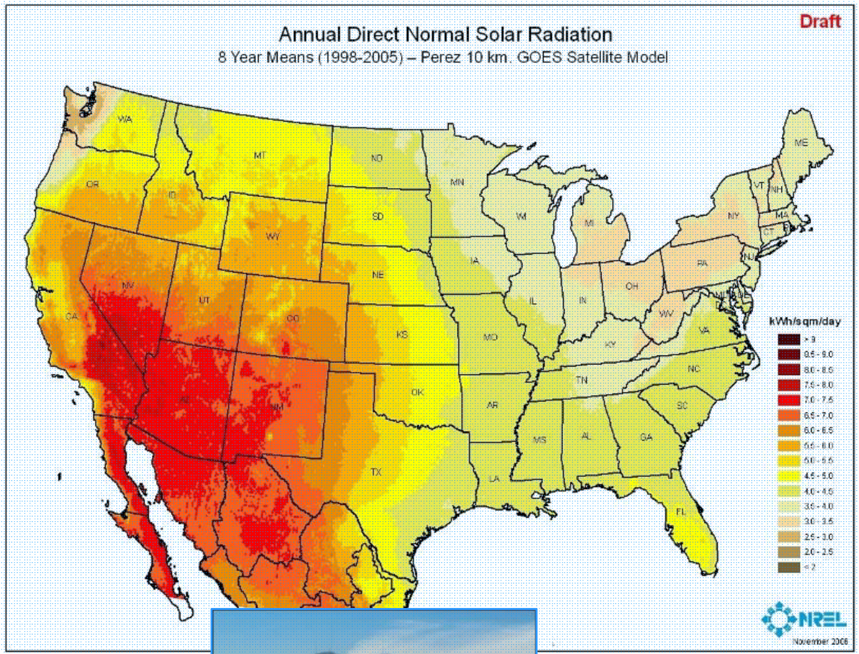
Economic Analysis



- Develop best practices for quantifying PV benefits.
- Evaluate how geographical diversity mitigates PV output variability.
- Evaluate costs due to unit commitment errors and impacts of increased forecasting quality.
- Examine enabling technologies and techniques, e.g. spatial diversity, orientation, and market-based.
- Examine electric or plug-in hybrid vehicles as PV enablers.
- Second-generation business models with whole or partial utility ownership of PV.

Objectives for Solar Resource Assessment

- Resource forecasting over various time steps, (1-3 hour), day ahead, seasonal, inter-annual
- Reliable, sub-hourly data sets
- Improve the spatial resolution of data sets
- Develop a user-interactive data archive.
- Focus new solar radiation products to support RSI requirements



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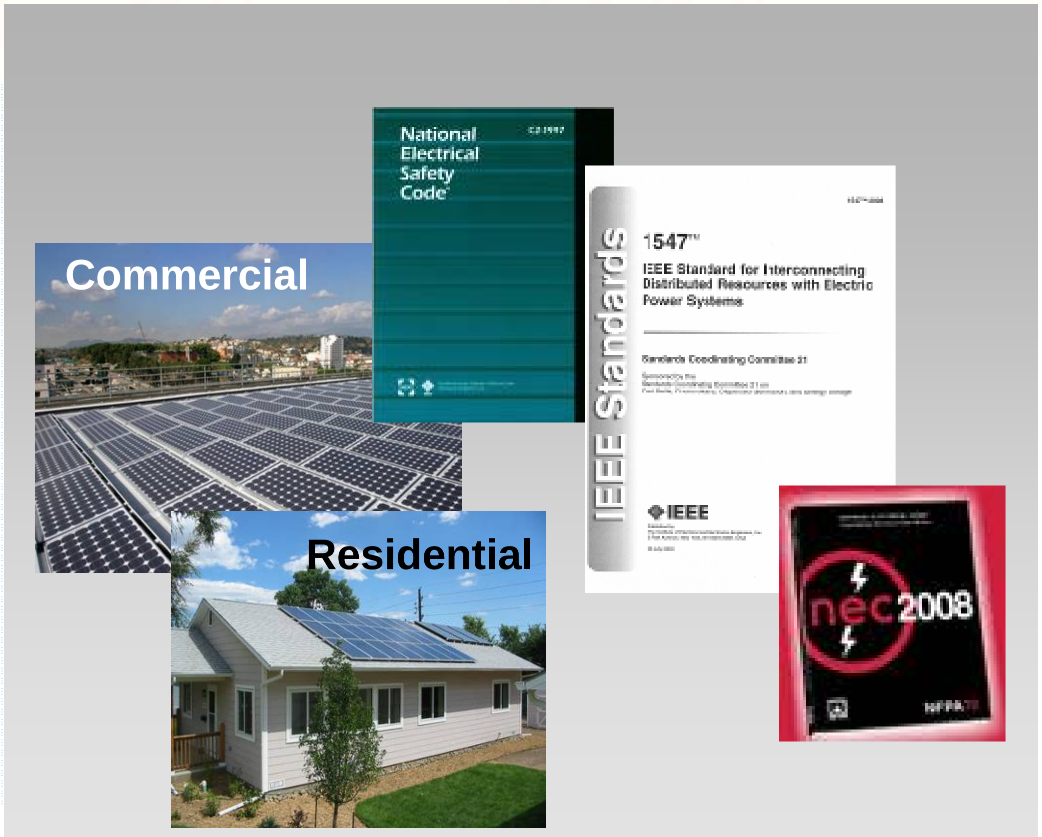
Objectives for Codes, Standards, and Regulatory Implementation



- Coordinated operation of all distribution equipment.
- Best practices for modeling renewables and energy storage.
- Best practices for T&D system planning and operation.
- Recommendations for enhanced regulatory implementation and practices.
- Improve methods/agreements for siting, permitting, & inspection.

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Renewable Systems Interconnection for Wind

*As a result of thirty years of R&D, wind turbines can now provide cost-effective, reliable clean energy. While we will continue to do R&D, there is **an increasing need for a Federal focus on removing barriers** to greatly expanding the use of wind energy, by building on the current robust market for wind energy in the United States*

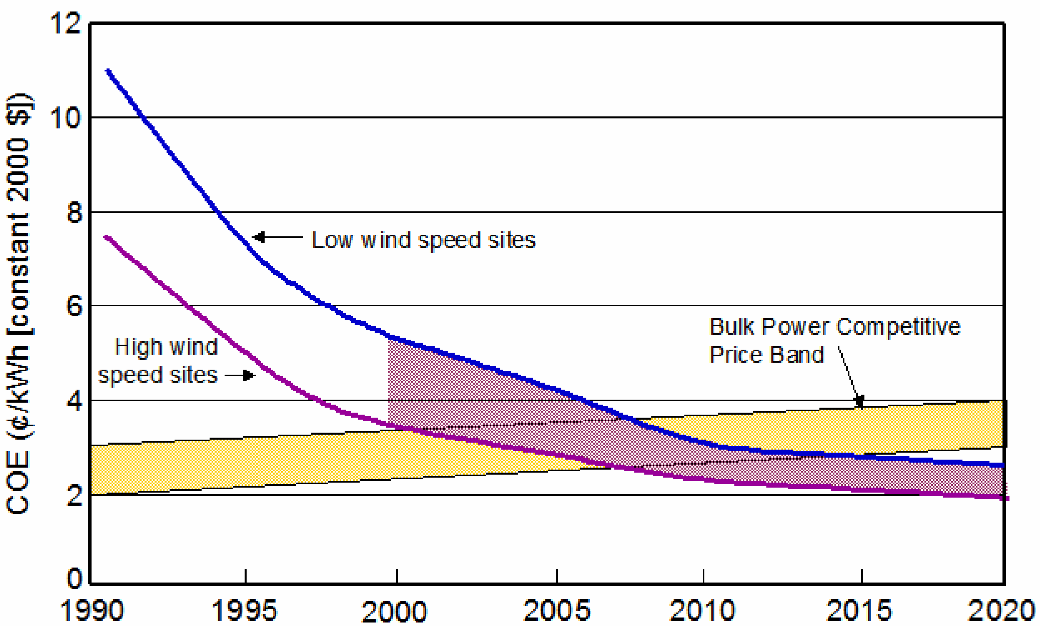
Removing Barriers to expand use of wind energy

RSI Goals:

- By 2010, facilitate the installation of at least 100 MW in at least 30 states.
- By 2018, facilitate the installation of at least 1,000 MW in at least 15 states.
- Provide information on wind energy interconnection to decision makers

RSI Activities:

- Wind Resource Analysis
- Interconnection Modeling Development
- Operational and Interconnection Studies
- Education & Outreach



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Wind Systems Interconnection

Challenges:
- Transmission Interconnection & Congestion
- Lack of knowledge of operational impacts and integration costs of wind energy
- Shortage of power system professionals with knowledge of wind energy
- Policy treatment of wind energy as an electricity resource

DOE Action:
- Assess wind's potential to serve our Nation's electricity needs
- Develop tools to assist the electric utility industry analyze wind energy
- Perform operational and interconnection studies with industry stakeholders nationwide
- Provide education curriculum for the next generation of wind energy professionals
- Reach out to federal, state, and local stakeholders on the challenges and solutions to wind energy integration

Results:
- Set the path for wind industry to accelerate its penetration
- Increase body of knowledge on wind/grid interconnection
- Help grow the delivery of emission-free energy from roughly 1 percent to the AEI's vision of 20 percent of our Nation's electricity usage

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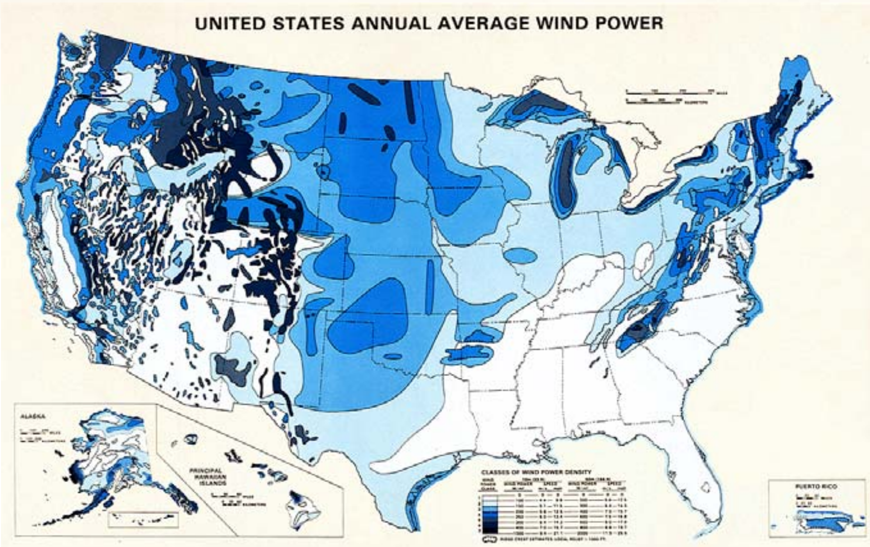
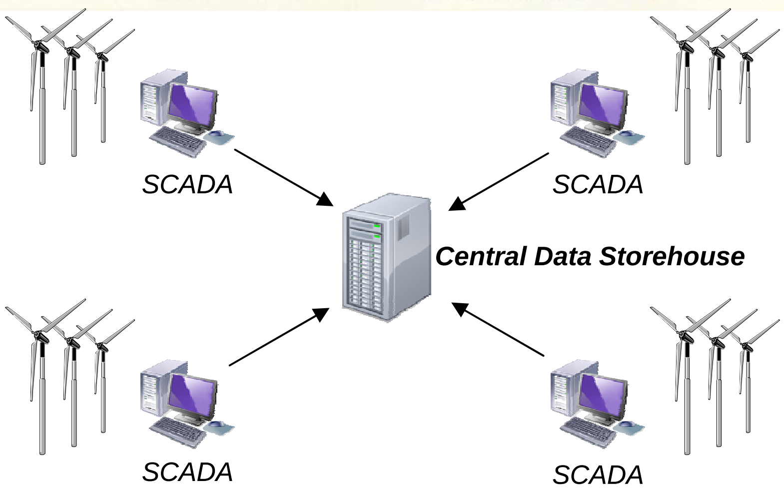
Wind Resource Assessment

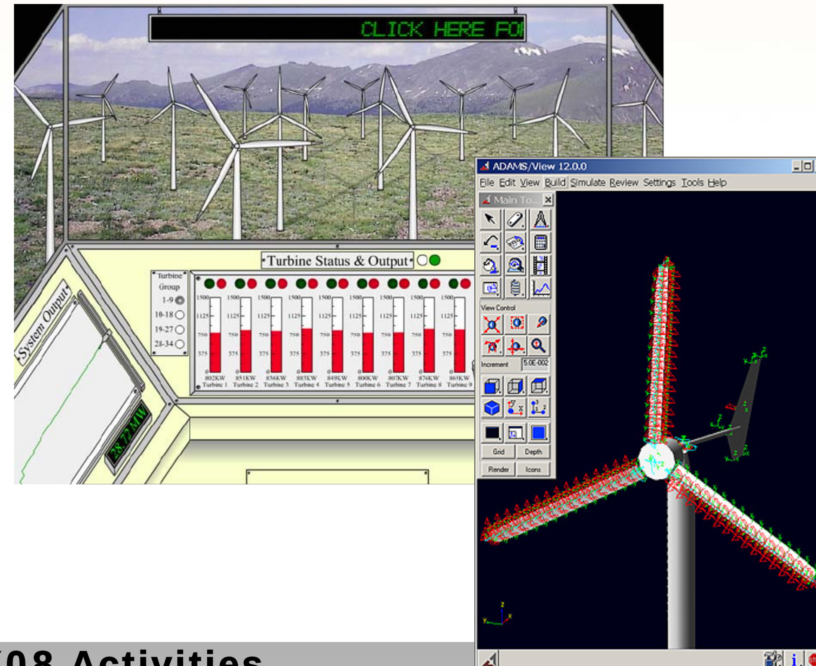




- **Meso-scale Modeling** – 100 meter wind speed modeling – first round to be completed in 2008
- **Forecasting** – Perform needs assessment, create a multi-year plan and quantify value
- **Tall Tower Measurement** – Complete a needs assessment and create a prioritized multi-year plan
- **Data Storehouse Creation** – Ensure that current and future data is available to the public in a “ready-to-use” form. Create an industry standard format
- **FY08 Activities**
  - Time Synchronized (10 minute) load, gen, and wind resource data
  - Wind Resource Model Validation
  - Wind Farm Data Monitoring
  - Resource Data Management & Visualization
  - Wind Plant output Forecasting

Modeling Methods Development

- **Dynamic Turbine Models**
  Create models of commonly used turbines for electric utility modeling software
- **System Operations Simulators**
  Provide the capability for electric utility operators to simulate operations with large amounts of wind energy on their systems
- **Wind Energy Integrated Resource Planning Tools**
  Build the tools utility system planners need to better integrate wind energy into their generation resource mix
- **Forecasting Methods & Tools**
  Provide control room level tools for system operators to anticipate the near term wind resource



- **FY08 Activities**
  - Wind Energy Operations Simulators
  - WINDS software model expansion
  - *Phasor Measurement for Wind Plants Pilot
  - Stochastic Unit Commitment Modeling
  - Advanced Production Cost Modeling
  - Wind/Hydro Operational Modeling

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Operational & Interconnection Studies

Providing decision support to electric power industry stakeholders

- **Market Value Analysis**
  Determine Wind's current and future value in electric energy markets including its value as a hedge against future fuel price increases, carbon tax, etc.
- **Interconnect Wide Studies**
  Western & Eastern grid wide, high penetration wind integration studies with broad stakeholder participation. The first of these will be completed in 2008.
- **Conditional Firm Transmission Tariff**
  Work with electric utilities on the effect FERC order 890 will have on the ability to integrate increasing amounts of wind energy into the transmission system.
- **Operational Integration Studies**
  Leading the effort to get control room level integration studies into the hands of stakeholders
- **Small System Integration**
  Investigate how wind integrates differently into islanded and small power systems.

Date	Study	Wind Capacity Penetra-tion (%)	Regula-tion Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commit-ment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Total Operating Cost Impact ($/MWh)
May '03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep '04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
July '04	CA RPS Phase III	4	0.46	na	na	na	na
June '03	We Energies	4	1.12	0.09	0.69	na	1.90
June '03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.6
April '06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April '06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97
April '06	Xcel-PSCo (1)	20	0.20	na	6.57	2.10	8.87 (2)

(1) Preliminary results based on scaling wind generation

Comparison of Cost-Based U.S. Operational Impact Studies

- **FY08 Activities**
  - *WGA Western Renewable Energy Zone Study
  - Southwest Wind & Solar Integration Study
  - Application of Energy Storage for Wind
  - Wind/Hydro Case Study Support
  - MISO/SPP/TVA Integration Study Support

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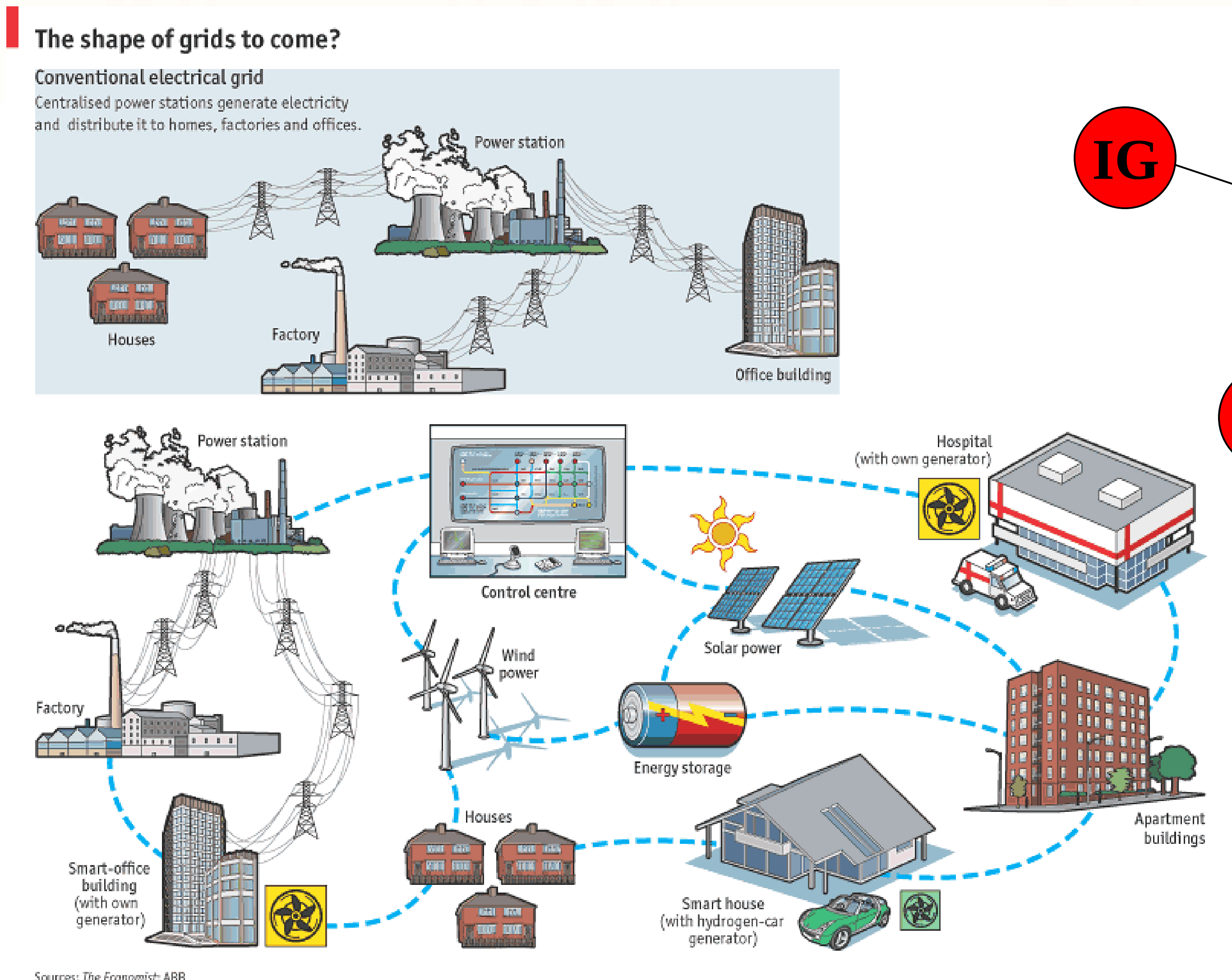
Outreach & Education

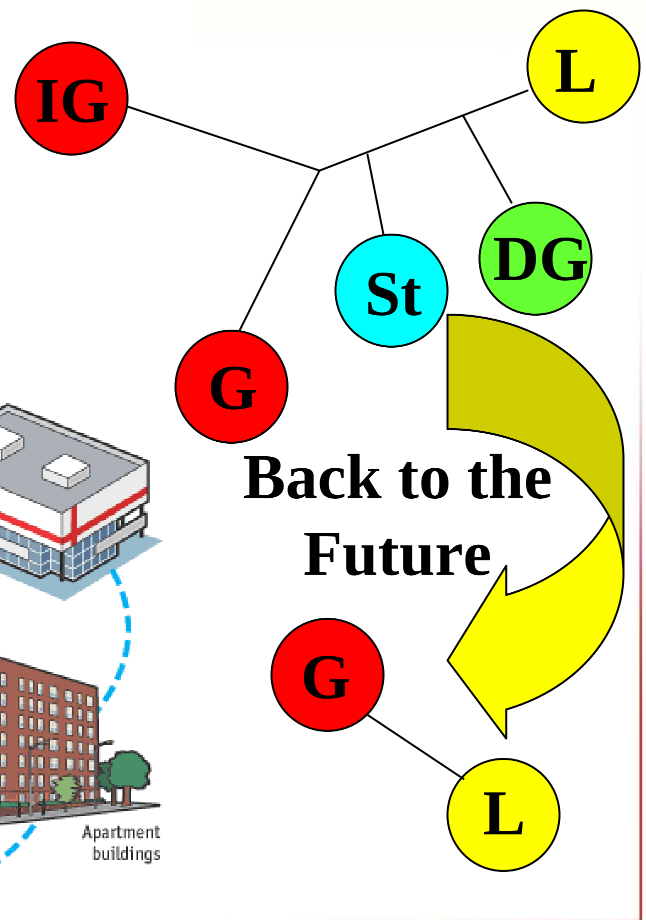
- **Engineering Program Development Fund** The creation of courses/programs for wind energy at the university level.
- **Trade School Program Development** Fund the creation of courses/programs for wind energy at the university level.
- **Policy Outreach** Create targeted informational materials for National, State, and Local policy and trade organizations to publish for their membership.
- **Wind Information Hotline** Create a single point of contact for stakeholders to obtain information about wind energy integration issues

- **FY08 Activities**
  - National Wind Coordinating Council Support
  - State Regulator & Legislative Decision Support
  - *University Curriculum Development
  - *PSERC/CERTS Wind Integration Research
  - NERC Standards Development

Sandia Funded Research

Potential Future Energy Grid





Courtesy of: California ISO

Innovative Control of the Electric Power Grid

Primary Goal:

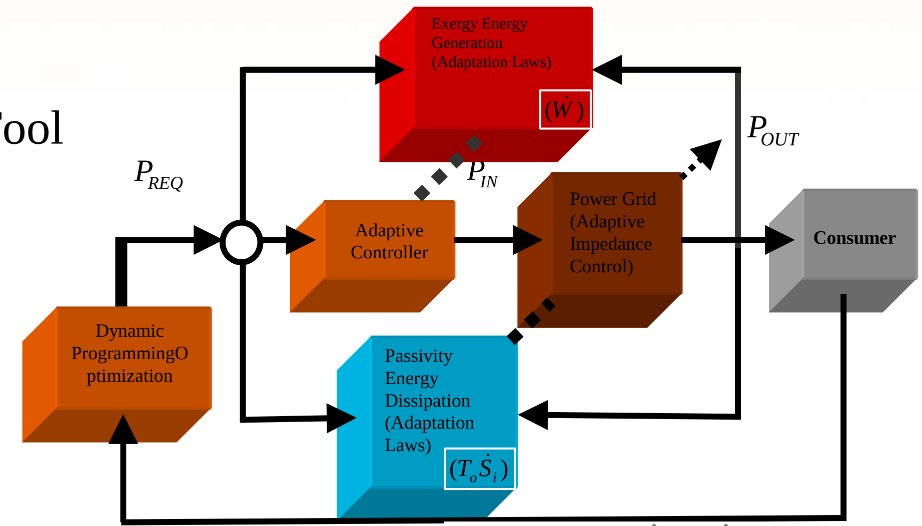
Develop Nonlinear Control Analysis Tool to Analyze and Design a Flexible, Adaptive Energy Infrastructure

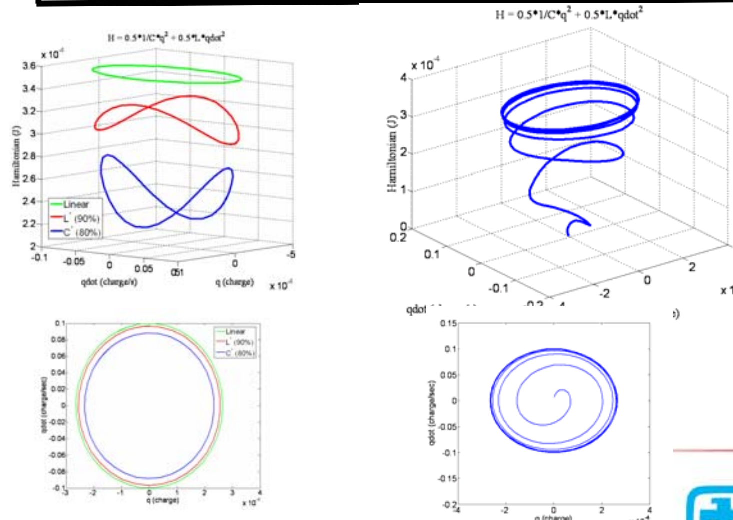
Three-Prong Approach:

I. Formulate general theory for nonlinear control

II. Develop an agent based network model to simulate the behavior of critical infrastructure

III. Design an experimental model of an electric transmission grid for hardware-in-the-loop testing





Intelligent Power Controller for Self-Organizing Microgrids

Project Purpose and Approach

Future energy systems will utilize multiple sources: solar, wind...along with energy storage systems to supplement utility power while enhancing energy surety. Efficient, self organizing microgrids power controllers can best match multiple sources to consumer demands. This LDRD is developing Silicon-Carbide power controllers-inverters and control algorithms for efficiency, safety and surety.

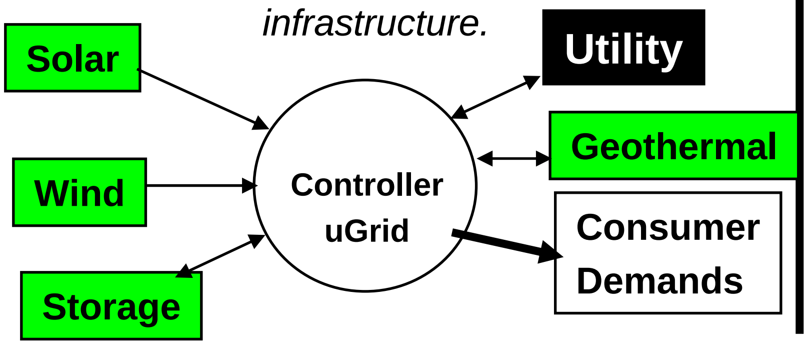
R&D Goals & Milestones

An intelligent microgrid resides on the consumer side of the utility grid with the ability to operate autonomously, meeting load requirements even with the loss of utility power.

- *FY08 – 300W Distributed Controller*
- *FY09 – Guidelines for control algorithms*
- *FY10 – Field test of distributed controller within Sandia's Distributed Energy Tech. Lab.*

Relationship to Other Work

This effort builds towards greater utilization of alternative energies, enables greater energy surety and aids in modernizing the US energy infrastructure.



Significance of Results

The successful competition of this effort will aid in meeting both military and civilian power needs from a diverse set of energy resources. An intelligent set of self-organizing power controllers allows for event handing to best meeting consumer changing needs.

Applications

A TRANSFORMATION IN HAWAII

Clean Energy Initiative

<u>*Benefits to Hawaii and the U.S.*</u>

- Less reliance on imported oil
- Reduction of GHG
- Accelerated rate, larger scale of EE/RE technology deployment
- More secure and robust T&D network
- Replication model throughout U.S. infrastructure (including DOD) plus international markets
- Energy market transformation model

Mesa del Sol

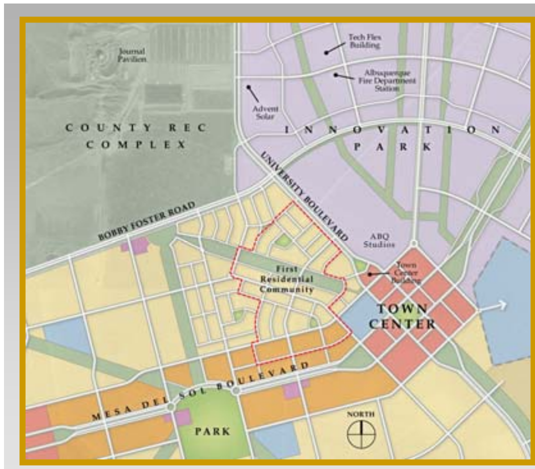
- A strategic partnership between Sandia and Mesa del Sol to:
  - **Demonstrate new technologies and methodologies in a "real community."**
  - **Focus on evolving energy and resource production, distribution, and consumption.**
  - **Meet sustainability objectives through renewable energy, its efficiency, and resilience.**

Facilities

- *Energy and Resource Showcase*
  - *Technology Demonstration Home*
  - *Town Center Site*
  - *100MW Concentrated Solar Power Plant*
  - *Education Portal for Sustainability*

Technology Areas

- Renewable energy technologies
- Fuel cells
- "Smart" power components
- Cognitive energy agents
- Control system technology
- Microgrid technology
- Security and resilience
- Trending, optimization, and reliability



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