



(Gerald Pearson, Daryl Chapin, Calvin Fuller)

Renewable Energy Research Centers at the Colorado School of Mines

P. Craig Taylor

Energizing Tomorrow

June 12, 2009

**Supported by DOE, NREL, NSF, and 20 Industrial
Partners**

Colorado Renewable Energy Collaboratory

Colorado Center for Biorefining and Biofuels

Center for Revolutionary Solar Photoconversion

Center for Research and Education in Wind

Solar Technology Acceleration Center

Colorado School of Mines (CSM)

**Renewable Energy Materials Research Science and
Engineering Center (NSF) (CSM, NREL)**

Colorado Fuel Cell Center (CSM, NREL)

Golden Energy Computing Organization (GECO)

Center for Hydrates

Journal of Renewable and Sustainable Energy (AIP)

Center for Revolutionary Solar Photoconversion

Revolutionary: Novel paradigm-altering approaches to solar fuels and solar electricity that exhibit both very high conversion efficiencies and low cost/unit solar collection area to produce fuels and electricity with resulting energy costs (\$/Mjoule) comparable to current energy production from fossil fuels.

Solar Photoconversion: Processes that produce solar electricity and solar fuels directly in a single step via the interaction of solar photons with photon converters that are based on, solid state physics, chemical sciences, and biosciences. The areas of research being pursued include:

- **photovoltaics (inorganic and organic),**
- **photophysics,**
- **photoelectrochemistry,**
- **photochemistry,**
- **photobiology**
- **nanoscience**



Third Generation Solar Photon Conversion (current research categories)

- **Electricity production (photovoltaics):** the photoconversion processes yield electricity, as in solid state photovoltaic solar cells based on bulk semiconductor p-n junctions, but also include technologies based on the absorption of solar photons in molecular or polymeric chromophores, or in semiconductors in contact with electrochemical redox systems.
- **Photoconversion into liquid and gaseous fuels:** a one-step direct process where the fuel (for example hydrogen, hydro-carbons, or alcohols) is the initial product of a direct photoelectrochemical, photo-chemical, or photobiological process driven by solar photons.
- **Novel nanostructures and advances in nanoscience:** these technologies have already and will continue to play a major role in the science of *third generation solar photon conversion*.

- Access to large pool of solar energy research knowledge (spanning the past 30 years)
- Early access to new publishable basic research results funded by DOE
- Window on the latest advances in solar conversion
- Opportunities to recognize and form beneficial partnerships with other companies
- Strong educational opportunities, including sending staff to CRSP labs for hands-on experience and interactions
- Single point of interaction with all four research institutions for shared and sponsored research.
- Annual membership fees are leveraged: matched by State of Colorado funding and provide access to all shared research.

Founding

Applied Materials, Inc.
Ascent Solar Technologies, Inc.
DuPont
Evident Technologies, Inc.
Konarka
Lockheed Martin
Motech Industries
QuantumSphere, Inc.
Sharp
Solasta, Inc.
Sub-One Technology
SunEdison

Additional

General Motors
Toyota

CREC Center for Research and Education in Wind (CREW)



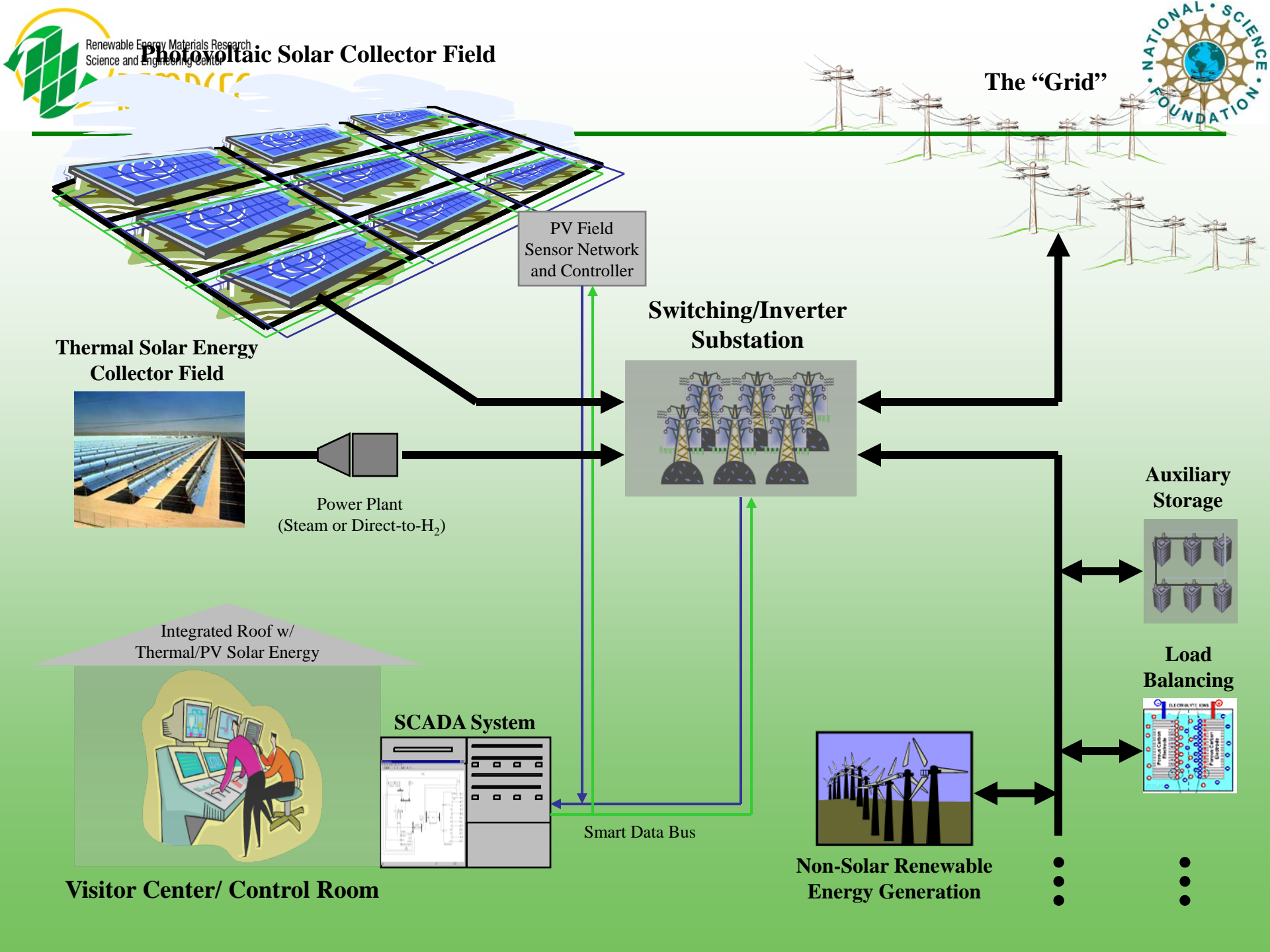
CREW Thrust Areas

- Turbine Modeling
 - Model development and validation
- ▶ • Turbine Testing
 - Testing and certification of field turbines and turbine components
- ▶ • Electrical systems
 - Integrid Laboratory
 - Grid modeling
 - Power converters
- ▶ • Atmospheric sciences
 - Measurement of wind environment
 - Simulation of wind fields and turbine response
- ▶ • Control of wind energy systems
 - Individual turbine control
 - Wind farm design and control
- ▶ • 60+ CREW experts in these areas



Solar Technology Acceleration Consortium





- **PV Manufacturing**
- **Distribution and Transmission**
- **Hybrid Power Control for Renewable Energy Applications**
- **Direct Solar-to-Hydrogen Conversion**

Colorado Fuel Cell Center

Housed in the General Research Laboratory

- Half of top floor dedicated to CFCC
- 3850 sqft research laboratories
- 1420 sqft office and conference



CFCC

- Joint venture with the National Renewable Energy Laboratory (NREL)
 - Close coupling with industry
 - CFCC laboratory space in General Research Laboratory building; ribbon-cutting ceremony May 9, 2006
 - Both solid oxide (high temperature) and polymer-electrolyte membrane (low temperature) fuel cells
 - Director, Professor Neal Sullivan
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Renewable Energy Materials Research Science and Engineering Center

- Colorado School of Mines
- P. C. Taylor, R. T. Collins, A. M. Herring, C. A. Koh, B. M. Olds
- Supported by
 - National Science Foundation
 - State of Colorado
 - Colorado School of Mines

24 NSF Materials Research Science and Engineering Centers Nationwide

- **13 New Centers Include:**
 - **University of Chicago**
 - **Princeton University**
 - **Harvard University**
 - **Massachusetts Institute of Technology**
 - **University of Colorado at Boulder**
 - **Colorado School of Mines**

Research and Engineering

- **Innovative and transformative research and engineering on materials for renewable energy applications**

Human Resource Development

- **Education of the next generation of renewable energy professionals**
- **Outreach to students and the community**
- **Promotion of diversity in faculty, students, and future students**

Advantages to NREL

- Access to students and research associates
- Ability to mentor students
- Joint appointments

Advantages to CSM

- Access to experts in materials for renewable energy
- Access to advanced equipment



**Colorado Renewable
Energy Collaboratory**

**Seamless interactions
with NREL and University
of Colorado**

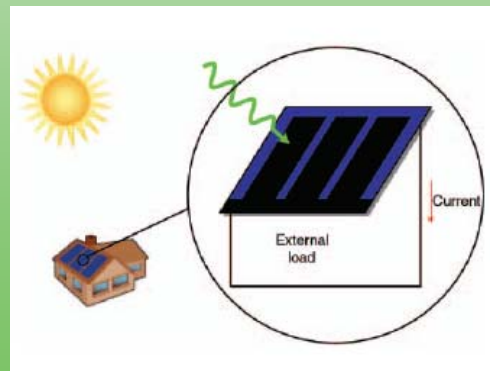
IRG1: Materials for Next Generation Photovoltaics

(Five Graduate Students, One Postdoctoral Fellow)

PV electric power today is more expensive than coal

Incremental changes in materials will not get us where we need to go

A fundamental understanding of nanostructured and other PV materials is essential to make transformative changes in solar panels



IRG2: Advanced Membranes for Energy Applications

(Five Graduate Students, One Postdoctoral Fellow)

Membranes play a critical role in renewable energy technologies

Current membranes are a weak link in many applications

A fundamental understanding of ionic transport is essential to make transformative changes in membrane materials



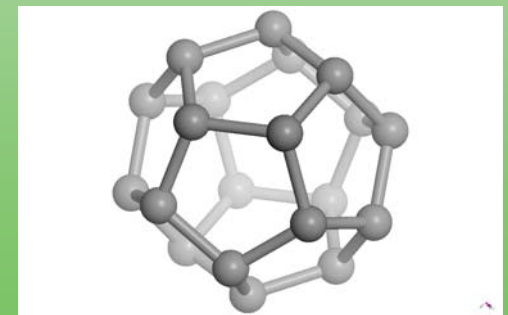
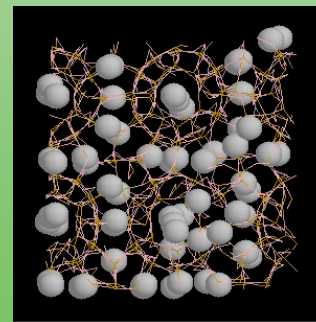
Initial Seed Project: Clathrate Hydrates and Silicon Clathrates for Storage of Fuels

(One Postdoctoral Fellow)

Storage plays a critical role in renewable energy technologies

Current storage materials are a weak link in all applications

A **fundamental understanding** of the incorporation of **guest molecules in clathrates** is essential to make transformative changes in these storage materials



Seed Grant Management

- Initial seed chosen by internal competition
- Request for proposals this semester
- Additional seed grant/grants to start fall 2009/
- Managed initially by Carolyn Koh

- **All inorganic thin-film PV technologies**
- **Next generation PV R&D companies**
- **Fuel cell membrane companies**
- **Separation membrane companies**

2 International Collaborations

- **Imperial College, London (Kucernak)**
- **University of New South Wales (Green)**

Under-represented Institutional Collaboration

- **Salish Kootenai College (Olson)**

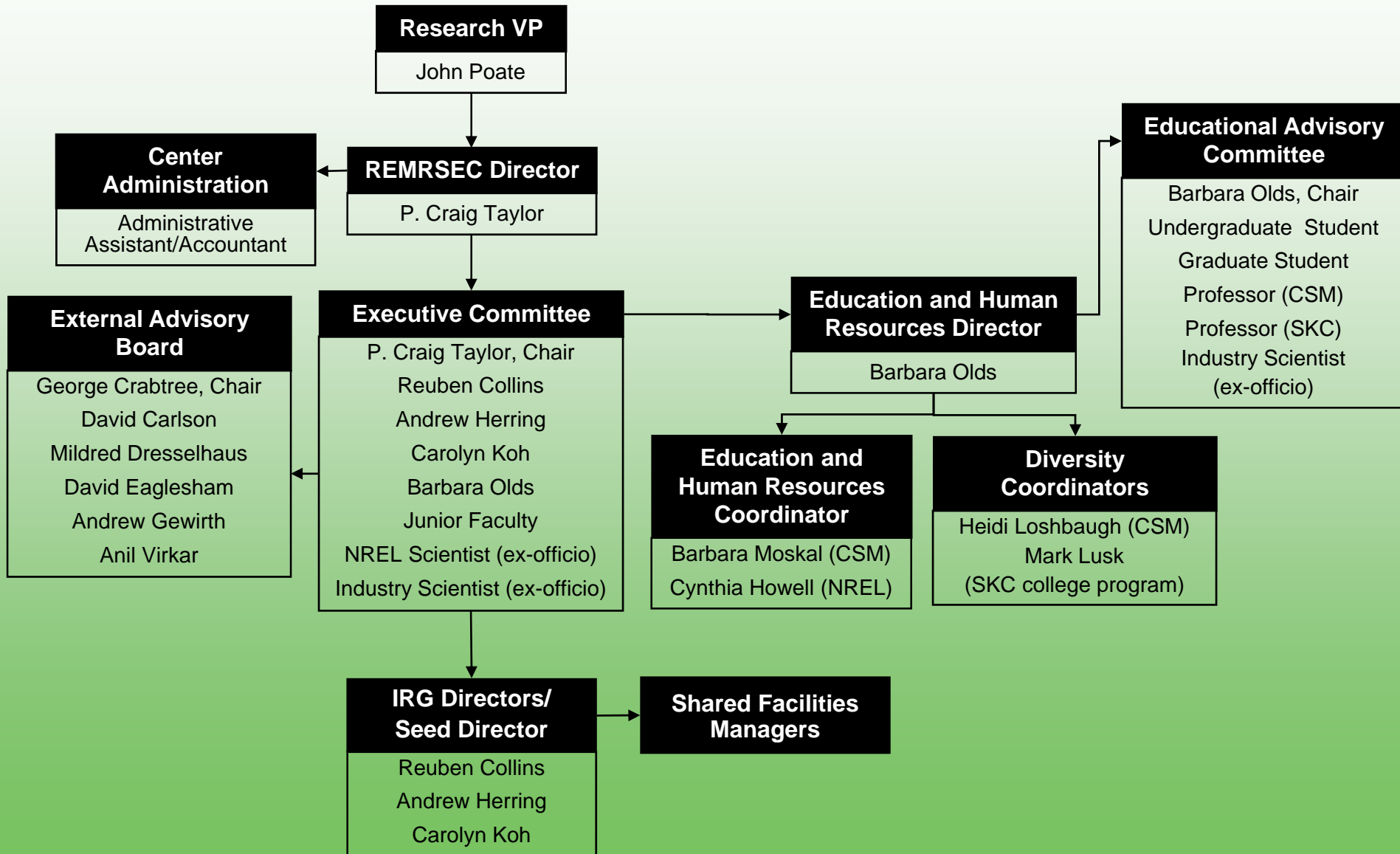
Goals: Education, Human Resources and Diversity

- Prepare undergraduate and graduate students to embark on careers in renewable energy fields
- Provide undergraduate and graduate students with research experiences in renewable energy
- Expose K-12 teachers and students to concepts of renewable energy
- Improve the recruitment and retention of female and minority undergraduate and graduate students and faculty

Five existing centers associated with the REMRSEC

- **Center for Solar and Electronic Materials (CSEM) Processing Laboratory**
- **Colorado Fuel Cell Center (CFCC) Laboratory**
- **Photonics and Ultrafast Laser Science (PULSE) Laboratory**
- **Colorado Energy Research Institute (CERI) Characterization Laboratory**
- **Golden Energy Computing Organization (GECO) Computing Cluster**

Management Structure



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(REMRSEC)

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Sun Edison/EXCEL Facility Alamosa, CO



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