Outline for Today

1. **Who**
   - is CH2M HILL and the Solar PV Design Team?

2. **What**
   - makes up a solar PV power plant, and what we do for our clients?

3. **Our**
   - tools and some other projects that are underway.
Safety Message

When you use a mobile while driving, your head is somewhere else!!

Source: adsoftheworld.com, La Cocina Publicidad
Committed to Health and Safety

CH2M HILL is committed to building a world-class health, safety, environment, and quality program. The Target Zero program seeks to eliminate all safety hazards and violations for all employees.

• Health, safety, environment, and quality
  – HSE&Q is a far-reaching initiative that encompasses employee behavior in the workplace, on the jobsite, and at home
  – Practically, safety is continually reinforced with basic training for every employee and an online resource for education, information, reference, and metrics
CH2M HILL Today

We are a global leader in:
consulting, design, design-build, operations, and program management.

• Headquartered in Englewood, Colorado
• Operations on all continents
• 30,000 employees worldwide
• 100 percent owned by our employees
• Broadly diversified across multiple business sectors
• US$6.4 billion in revenue

ENR Ranks

CH2M HILL

#1

Program Management
Environmental Firms
 Pipelines Design
Sewer/Wastewater Design
Sewerage and Solid Waste
Site Assessment and Compliance
Solar Power Design
Wastewater Treatment Plants
Water Treatment and Desalination Plants

(ENR rankings as of July 2011)
Established in 1946 by three engineers and a professor, CH2M HILL operated from its very beginning on four simple values: take care of clients, deliver great work, do right by employees, and stay true to our integrity and honesty.
# Diverse Business Portfolio

30% of our business is Energy

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<thead>
<tr>
<th>Energy</th>
<th>Facilities &amp; Infrastructure</th>
<th>Government</th>
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<tbody>
<tr>
<td>Energy and Chemicals</td>
<td>Transportation</td>
<td>Nuclear</td>
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<tr>
<td>Water</td>
<td>Industrial &amp; Advanced Technology</td>
<td>Government Facilities and Infrastructure</td>
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<tr>
<td>Power</td>
<td>Operations and Maintenance</td>
<td>Environmental Services</td>
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<td>Sustainability</td>
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<td>Delivery Excellence</td>
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1. Who is the Solar PV Design Team?
Energy for Water Consumption per capita in Year 2000 compared to predicted in 2050
Technologies that we use for our designs

- Solar PV
- CSP
- Biomass
- Geothermal
- Wind
The Solar Photovoltaic (PV) Design Team

DESIGN,  BUILD,  CONSTRUCTION MONITORING

- **Typical Work Products:**
  - Solar Site Assessments
  - Preliminary Designs and Analysis
  - Layout of PV Power Plant
  - Cost Estimates
  - Economic Analysis – tax credits, green credits, and pro formas
  - Detailed Designs
  - Work with Local Contractors to Build the PV Power Plants
Solar PV Projects and Water Facilities

10 MW Solar Plant at MASDAR

75 kW roof mounted PV on North Brunswick NJ, Water Treatment Facility

Built above the existing CAVSARP facility.
3 MW Solar Plant for City of Las Vegas at the Water Pollution Control Project – Completed in August 2012

66 MGD Waste Water Treatment for Las Vegas
3 MW Las Vegas Plant Under Construction
Las Vegas Solar Array – Tracking System
Conducted a detailed study and preliminary design for 5 MW PV plant to co-exist on land with Burrowing Owls. Solutions were difficult but possible.
New Project at Clark County Water Reclamation District
Nevada, Las Vegas – 10 to 20 MW Solar Plant on 100 Acres
Projects at Water Facilities Built by Others

- **Alvarado Water Treatment Plant**, San Diego, CA 1 MW atop water reservoirs; PPA with solar installer
- **West Basin Municipal Water District**, El Segunda, CA
- **Grit Handling Building** heated by Solar Thermal Collectors in Saico, ME
- **North Hudson Sewerage Authority**, Hoboken, NJ
Ideal Opportunities for Solar PV at Water Facilities

- Accessible space for PV installation (buffer zones, ponds, and available roof space)
- Access to the utility grid or a convenient point to interconnect to the building electrical service
- High electric rates paid to the existing electric utility
- Markets where utility, state or local incentives are available
- Good solar resource (South, or Southwest region of US, or international sites with high sun levels)
- Local solar contractors or financiers willing to build and finance the solar project through a third party power purchase agreement
Energy Fun Fact #1

- The first solar cells in the 1950s were about 0.5% efficient in converting sunlight. Today a module can convert sunlight to electricity at an efficiency of greater than 20%.

1 kW system:

- In 1950 = 2,100 square feet
- In 2012 = less than 100 Square feet

(4 kW system will supply enough for a small house during peak hours)
2. What makes up a solar PV power plant, and what we do for our clients?
Basic Types of PV Cells

- Monocrystalline Silicon
- Polycrystalline Silicon
  - Cast Polysilicon
  - String Ribbon Silicon
- Thin Film Cells
- Group III-V Technologies
  - Multi-junction Devices 20 to 41 %

12 to 21 % Efficiency
6 to 10 %
11 to 15 %
How Cells Work
How Single Crystalline Silicon cells are made

Feedstock melted into ingots in Furnace

Ingots sliced into wafers/cells

Cells are arranged and wired into modules

Start with basic sand/quartz
Exciting New Emerging Technologies

Nano-solar techniques
- NanoSolar – in California - Electrically Conductive Plastics
- Konarka – Polymer and dye-sensitized solar cell; have flexible cells about 5 % efficient

Multi-layered thin film
- Each layer is sensitive to different light frequency resulting in high efficiency
Innovative Applications in the Field
The Growth of the Solar Market (from 2007 forecast)

Actual 2011 ~27 GW (Photon Int’l)
Capacity 36 GW (predicted to exceed 66 GW in 2012)

Actual ~16 GW (European Photovoltaic Industry Association)

Source: Company analyst reports / FACC
Module Cost Decline as Industry Grows
(Source: Strategies Unlimited, PHOTON Consulting)
Figure 1: PV module experience curve 1976-2011 (BNEF, 2012a).

Bloomberg New Energy Finance (BNEF) 2012
United States Federal Tax Credit (called the ITC)
Commercial and residential customers with a tax liability receive a tax credit of 30% of the capital investment in a solar PV system. No limit on the total. For example, if it is a $1 million investment, tax credit is $300,000. Through 2016.

Many states have Renewable Portfolio Standards (sometimes referred to as mandates)
Electric utilities are required to purchase a pre-defined minimum amount of renewable energy. Some states such as Arizona have a specific carve-out for solar energy.

Electric utilities in some local areas offer cash incentives
Some electric utilities offer cash rebates for solar installations. In some cases the electric utilities purchase Renewable Energy Credits (RECs).

Web Site: DSIREUSA.org
Market Drivers
Map of US Renewable Portfolio Standards (DSIRE)
Solar PV Plant Major Components

• Solar Array
  – Solar modules will typically be wired in series to achieve a photovoltaic source circuit voltage of <1,000 VDC.

• Balance of System
  – Several source circuits will terminate in a master combiner box, and feed a central inverter.
  – The inverter converts 1,000V DC into 480V AC, and;
  – potentially a transformer
Basic Utility-Interactive System Diagram

Utility-interactive grid-direct (UIGD) system

- PV array
- dc disconnect
- Inverter
- ac disconnect
- Service entrance
- Utility grid
- Loads
Energy Fun Fact #2

- The first solar water heater commercial business started in 1895
- The “Climax” solar water heater sold for $25 to residences
- The average homeowner saved $9/year of coal, or gas
- By 1900 a total of 1600 systems in southern California were installed
- By 1923 inexpensive oil and gas wiped out the industry
3. **Some** of our design tools and other projects that are underway
Renewable Energy Group
Site assessments, Modeling and PV Plant Design

PV technologies
System types: tracking, fixed, concentrators

PVSYST
SAM
3-D modeling
Current project at WTP

One Evergreen 200/205/210 Watt solar module

Analysis by Kurt Lyell/AUS
Conceptual Layout: 502 kW

Analysis by Kurt Lyell/AUS
3D View

Analysis by Kurt Lyell/AUS
Large Scale Solar Power Plant in Arizona Adjacent to a Natural Gas Power Plant – CH2M HILL Design

50 MW solar PV plant. Electricity goes directly into the utility grid.

Will produce about 100,000 MWh/year.
18 MW plant in NJ – Challenge to follow the land contours
MASDAR CITY - What is it?

A Sustainable City

providing the highest quality of life with the lowest environmental footprint.

- Carbon neutral
- Zero waste
- Fossil fuel free zone
- Low water consumption
- Economically profitable

www.masdar.ae
Life in Masdar City – Masdar HQ Exterior
Life in Masdar City – Civic Square
Life in Masdar City – Streetscapes

Rendering  As built
Masdar Institute of Science and Technology
Completed PV System on Roof of MIST BUILDING
Dust - 15 to 20 % loss without brushing
Typical System Design Metrics and Costs

<table>
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<tr>
<th>Land (or roof)</th>
<th>4 to 5</th>
<th>Acre/MW</th>
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<tr>
<td>Electric Production</td>
<td>2,000</td>
<td>MWh/MW/yr</td>
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**Example**, a 10 MW sized PV plant could produce:

\[10 \, MW \times 2,000 \, \text{MWh/MW/yr} = 20,000 \, \text{MWh/year}\]

**NOTE:** Production varies by amount of sunlight and type of solar design.
Example: A 10 MW plant would cost $27.5 million installed.

- **Annual savings** = $100/MWh \times 20,000 \text{ MWh/yr} = $2,000,000/\text{year}
- O&M typically cost $10/MWh/\text{yr}$. Therefore, O&M = $200,000/\text{year}$
- **Simple Payback** = about 15 years \ ($27.5/\$1.8 \text{ million}$)

**NOTE:** With tax credits and third party financing, a detailed financial analysis would indicate a payback from 5 to 10 years
Other Financial Models

- **Third Party Financed:**
  Economics can look more attractive with detailed economic analysis and when financed by a third party through a power purchase agreement (PPA).

- **Finance/Owner Transfer:**
  Third party finances and operates the plant for pre-determined time period, then turns ownership over to municipality. Could be a lease arrangement.
100 MW PV Plant for a Developer in Jordan

- Technology assessment
- Preliminary designs and specifications
- Market analysis
- Regulatory setting
- Preliminary environmental and social impact assessment
- Host country impact analysis
- Financial analysis
Two PV plants in India for Solar PV Developer

- Meteorological stations installation
- Solar weather data analysis
- Preliminary designs and specifications
- Transmission system assessment
- Preliminary environmental analysis
- Technical specifications for EPC bids
- Financial analysis
Solar Meteorological Station - Bankura
Met Station with Permanent Wind Tower
Useful Web sites

- Interstate Renewable Energy Council
  WWW.IRECUSA.ORG

- National Renewable Energy Laboratory
  www.nrel.gov/solar/

- Sandia National Laboratories
  www.sandia.gov/energy-water/
The average electric usage in homes is about 10,000 kWh per year in Texas.

Lance Armstrong used approximately 100 kWh of energy (in food) to ride the Tour de France: 2,100 miles. That is about $10 of electricity.

A car would have used about 8,800 kWh equivalent, or about $880 of electricity.
Questions?

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