INDEPENDENT ENGINEER PERSPECTIVE
DIFFERENTIATING QUALITY PV
SAN FRANCISCO, CA
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Presented by : Ray Hudson – Director Solar Energy
BEW Engineering Overview

• **BEW Engineering**
  - Founded 2002 predecessor solar experience back to 1980s
  - San Ramon, CA, San Francisco, CA, Boston, MA, Seattle, WA, Houston, TX, Fort Collins, CO

• **Acquired by DNV in 2010**
  - Worldwide consultancy
  - Headquarters in Oslo, Norway

• **DNV acquired KEMA in February, 2012**
  - International Energy consultancy
BEW PV Services Today

- Technical Due Diligence – System-Level Evaluation
  - Before, during and after construction
  - Independent Engineering clients
    - Banks
    - Other financial institutions
  - Owner’s Engineering clients
    - Developers
    - Equity holders
- Technology Review “Bankability” – Key Component Review
  - Equipment manufacturers
    - Modules
    - Inverters, mounting systems
    - Mounting and Tracking systems
    - BOS
- PV System Design
  - Commercial
  - Utility Scale
- Other (testing, research, training, resource measurement...)

a DNV company
BEW TYPICAL SYSTEM REVIEW ELEMENTS

• Site evaluation
  • Topography, Shading, Soiling
• Solar resource determination
  • Long term
  • Variability P(X)
• Design and equipment review
  • Good practices
  • Safety
• Energy estimate – used for financial modeling
• Document review
  • Contracts
  • Permits
• O&M cost estimate
• Construction review
• Overall Risk Assessment
• Inspection
• System Test
• Performance Evaluation
• Final Completion
BEW IE PERSPECTIVE

- Clients need objective advice from an Independent Engineer
- Expertise and experience in PV systems, components, and history
- Objective
- Thorough
- Incorporate best available information
- Use best available methods
- Goal is accuracy!
INDEPENDENT ENGINEER VIEW

• Types of investors – different perspectives
  • Long-term financing
    • Concerned with long-term performance (5-20+ years)
  • Construction finance – short-term loan
    • Want to ensure completed project can be sold

• Long-term revenue stream depends on
  • Installed cost
  • Energy generation
  • O&M costs
  • Contract items (PPA energy rate, performance guarantee,...)
  • Economic factors (Interest rate, ITC, other incentives...)

• Identify and quantify project risks and uncertainty
  • Uncertainty in long term vs annual
  • Downside cases

• DETAILS MATTER!
  • Must be considered appropriately
GAPS AND OPPORTUNITIES FOR IMPROVEMENT

• Component Modeling – better data
  • Modules
  • Inverters

• Resource data
  • Key input to energy modeling
  • More and better sources

• Field system performance data
  • Feedback for refining system energy prediction methodology
  • Detailed review of individual long term systems

• O&M cost modeling
  • Additional and more complete data for improving models

• Uncertainty and Risk Analysis
  • Standardized methods and terminology
  • Understanding limitations

• Contractual agreements
  • Standardization opportunities
Predicting Energy Generation – PV Component Modeling

• PV Module
  • PV datasheets are essentially useless for modeling – insufficient data
  • Lack of transparency from manufacturers
  • Third party data needed for model
    • Data is needed from a statistically significant population of modules
    • Data is needed for specific model and power rating (i.e. don’t use 260W data for 280W module)
    • IV curves over range of irradiance levels (100W/m² to 1200W/m²)
    • IV curves over a range of temperatures (0°C to 80°C)
    • Measurements and models of seasonal variability for thin film
    • Reflection properties of glass

• Inverter
  • Thanks to CEC requirements, independent performance test data readily accessible for efficiency
  • Challenge for non-UL listed inverters to provide same data quality - standardization
  • Standards for derating on other factors (Voltage, temperature, elevation...)
  • Reliability data
  • O&M Cost data

• Degradation
  • Measurements of module light-induced degradation
  • Measurements of module long-term degradation
  • Measurement of system long term degradation
Thank you!

Further information at www.bewengineering.com

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## IE/OE Menu

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<td>Site Visit, availability of site host personnel</td>
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| Evaluate site for suitability/feasibility of proposed installation; potential impact of the following on system construction and operation:  
  - Solar Resource  
  - Topography/shading  
  - Site/soil condition  
  - Security  
  - Environmental factors  
  - Military, other considerations | Site Visit, availability of site host personnel  |
| **DESIGN & EQUIPMENT REVIEW**     | Design drawings, project schedule, product Spec and Warranty Sheets. Interviews w/ engineers and designers |
| Review design for code compliance and conformance to customary solar engineering practice. Evaluate key Components:  
  - Modules  
  - Inverters  
  - Tracker design  
  - Balance of system  
  - System integration | Design drawings, project schedule, product Spec and Warranty Sheets. Interviews w/ engineers and designers |
| **PERFORMANCE ESTIMATE**          | Performance data, designer assumptions, Performance Guarantee |
| Estimate system performance:  
  - Site-specific solar resource  
  - System power ratings (cc/ac,STC/PTC, etc.)  
  - 1st-year energy production  
  - Life time energy production, including degradation | Performance data, designer assumptions, Performance Guarantee |
| **CONSTRUCTION SUPPORT REVIEW**   | Supply & service contracts, project schedule, key subs list |
| Review and investigate Construction Support, identify potential hurdles & recommend solutions:  
  - EPC Construction review  
  - Supply & service contract terms & conditions  
  - Key subcontractors  
  - Installation schedule  
  - Performance guarantee review | Supply & service contracts, project schedule, key subs list |
| **O&M REVIEW**                    | O&M Contract & Manual                             |
| Review and investigate Operations and Maintenance, identify potential hurdles and recommend solutions:  
  - O&M cost estimate  
  - O&M contract terms & conditions  
  - O&M Manual  
  - Key subcontractors | O&M Contract & Manual                             |
| **OVERALL RISK ASSESSMENT**       | Schedules & Contracts                             |
| Summarize project risk in terms of potential impact on:  
  - Construction schedule  
  - System performance  
  - Long term reliability  
  - Performance guarantee review | Schedules & Contracts                             |
| **PERMIT STATUS REVIEW**          | Permit submittals and approvals                   |
| Identify key permit and schedule milestones. Evaluate on-going status of permits including:  
  - Building permits, easements, grading, dust, etc.  
  - Incentive reservations & proof of progress  
  - Utility interconnection/net metering/ FERC/ISO  
  - Environmental permits | Permit submittals and approvals                   |
| **SITE INSPECTION**               | Construction drawings and project schedule         |
| Visit site to:  
  - Verify as-built installation  
  - Evaluate workmanship  
  - Verify permit compliance  
  - Verify schedule conformance  
  - Perform or witness sub system testing  
  - Develop punch list and check status as necessary | Construction drawings and project schedule         |
| **SYSTEM TEST**                   | System fully operational and access to performance data where applicable |
| Witness or review data set to:  
  - Verify minimum period of continued operation  
  - Assess actual vs. predicted output  
  - Other contractual measure of acceptable performance | System fully operational and access to performance data where applicable |
| **PERFORMANCE EVALUATION**        | System fully operational                           |
| Complete or spot evaluation of array, tracker, inverter through the use of:  
  - Spot voltage and current measurements  
  - IV curves  
  - As-installed array and system ratings  
  - Independent performance monitoring | System fully operational                           |
| **FINAL COMPLETION**              | Notice of Interim Completion prior to visit, Notice of Final Completion issued by the installer |
| Verify the completion accuracy of all items to be declared listed on the Final Completion Notice, such as:  
  - System ready for full, uninterrupted commercial operation  
  - System passed inspections with AHJ  
  - Utility interconnection installation evaluation complete  
  - System tests passed successfully | Notice of Interim Completion prior to visit, Notice of Final Completion issued by the installer |