June 25, 2015
Solar Energy for Municipal POTW Facilities
CSWEA / IAWA Solar Summit
Agenda

• Project planning
• Design & installation considerations
Services & Credentials

Solar & Wind Energy Development & Installation
- Licensed PE’s, licensed Engineering Corporation
- NABCEP-certified designers & installers
- Turnkey Integration - Design, Finance, Build, Operate, Maintain
- Tailored, Project-Specific Delivery Structures
- Independent Commissioning
- Forensic Engineering & Expert Witness
- Developer Support Services
- Monitoring & Maintenance Contracts
- Design & Procurement Support
- Energy Storage Systems Design & Construction

Energy, Microgrid & Efficiency Services
- ASHRAE Energy Audits and Energy Modeling
- Energy Efficient New Construction & Upgrade Projects
- EnergyStar Certification
- Financial Modeling, Incentive Capture
- Electric Vehicle charging stations

Project goals: Safety, Performance, Aesthetics
Renewables and Efficiency Clients

Commercial – Government – Industrial – Institutional

Mixed Use / Hospitality / Data Centers / Food-Beverage Processing
Public Attractions / Performance Venues / Schools

- St. Louis Cardinals (20+)
- US Bank (9)
- St Louis Science Center (3)
- Novus International (2)
- Washington University (20+)
- Missouri Botanical Garden (3)
- Drury Hotels (4)
- University of Missouri St Louis
- MasterCard International (2)
- Holiday Inn Express (2)
- McCormack Baron Salazar (3)
- Yanbu Royal Commission
- Bahamas Water Authority
- St Louis Rams
- Hertz Car Rental (2)
- Various US K-12 schools (20+)
- Fontainebleau Resorts
- Nestle Purina PetCare (2)
- Pageant Theatre
- United Health Care / MetLife (2)
- Harrah’s Entertainment
- Sheraton Hotels
- Enterprise Rent-A-Car
- US Army Corps of Engineers (4)
- Tropigas Panama (2)
- Peter Island Resort and Spa (3)
- IKEA
- Schlafly Bottleworks
- Anheuser Busch / InBev
- MDNR State Park System
- Better Life Products (2)
- Muny Opera
- Moonrise Hotel (4)
- Express Scripts (2)
- Webster University (5)
- Illinois Institute of Technology (4)
- Commerce Bank (5)
- City of Columbia Water & Light
- Seiler Instruments

Renewables development over 500 projects totaling over 120 MW
LEED & Energy Star projects from 10,000 sf to 9,000,000 sq.ft.
50+ million kWh/year energy reduction in clients' buildings.

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Capacity Planning with Solar Integration

24-hour base load + office-hours variable load
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

Small solar array
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load
Small solar array

*Resulting utility load on a sunny day*
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

... Larger solar array

Resulting plant load on a sunny day
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

... Larger solar array

Resulting plant load on a sunny day
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

... Larger solar array

*Plant load supplied 100% from solar at midday*
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

... Larger solar array

*Plant begins to backfeed the grid at midday*
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

*Utility may reimburse for that backfed energy*
Capacity Planning with Solar Integration

24-hour base load + office-hours variable load

*Energy efficiency reduces plant load for PV and grid*
Capacity Planning with Solar Integration

What happens on a cloudy day?

*Variability in solar production, variability in utility demand*
Capacity Planning with Solar Integration

Q: What is the capacity that we can physically install?  
   *Future access and maintenance*

Q: What is the best system design configuration for our needs?  
   *Racking, tilt, power electronics, azimuth*

Q: How much energy will that system produce in a year? An “average” day?  
   *System yield, energy/power for Chicago: 1,250-1,350 kWh/kW*

Q: How will it affect the plant utility expenses?  
   *Energy, fuel, delivery, & tax, but not power demand*

Q: Will the utility allow it, and what processes are required?  

Q: What are the impacts of weather and climate?  
   *Snow and wind load, 30-year averages*

Q: What is the financial performance and can it be financed?  
   *Tax incentives, third-party options*

Q: How do we manage the process and ensure success?  

Q: What is the schedule, and will it interrupt operations?  

Q: What should we expect during operation?
Project Planning

Capital planning: one budget cycle?
Target financial performance
Goals + funding = project scope
Location: roof, ground, structure
EPC cost: $2.00/W (roof) to $2.30/W (ground) *
Roof protection, warranty, life expectancy
Schedule
• Engineering: 1-2 months
• Procurement: 1-3 months
• Construction: 300-400 man-hours / 100kW

* Typical pricing based on 500kW system size
Project Planning

Team selection & delivery method
• Responsibility for quality assurance for the Owner
  o In-house O&M team
  o Corporate capital construction department
  o Consulting architect
  o Specialized owner’s agent or construction manager
• Financing: Owner- or third-party financed

Competitive bidding
• Choose engineering or CM based on qualifications
• Bid equipment and installation labor (most costly)
• RFP and Specification for < 10% cost variance
• Bonding and liquidated damages
• Don’t rush it!
Stuff you learned in High School ... if you were paying attention

POWER = speedometer kW, kilowatts

ENERGY = odometer kWh, kilowatt-hours
Grid-Interactive PV System

The Grid-Interactive Inverter is a "current source"
- Like a hose, pressure pushes the flow of water
- Produces current and pushes it to the Main Panel
- Excess current pushes out through the Meter and to the Grid

The Utility Grid is a "voltage source"
- Like a large lake – lots of water at a steady level (voltage)
- Electricity will flow into the building if loads are not met by solar array
Grid-Interactive PV System

Normal Operation – “Anti-Islanding” Mode

- Grid-interactive inverter senses voltage or frequency out of tolerance range
  - Inverters stop exporting power within 2 seconds (UL-1741)
- All AC loads in the building are de-energized
- DC conductors are still “hot” until the first disconnect point
- Inverter monitors grid, switch on after 5-minute steady-state voltage/frequency
Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

Normal Operation

- Automatic Transfer Switch - Normal
- Block heater used to limiting outage duration
- Grid-Interactive PV Inverters – On / Normal
  - Pushing current to Main Panel

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Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

Utility Grid Failure

- All loads fail momentarily (unless protected by UPS)
- Automatic Transfer Switch – Normal
  - ATS senses failure and starts backup sequence
- Grid-Interactive PV Inverters – Fail off within 2 seconds (UL-1741)
  - DC side still “hot”
Emergency Backup Mode

- *Genset started*
Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

Emergency Backup Mode

• *Genset started*

• *ATS switches to genset*
  - All loads energized

• *Genset voltage pushed to Inverters*
  - Inverters begin monitoring voltage and frequency of the genset
Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

Emergency Backup Mode

- After 5 minutes of steady-state operation, Inverters start up and begin exporting power
Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

**CAUTION: Inverters can destabilize loads and damage genset!**
- Clouds will cause short-duration current and power fluctuation
- Damage to sensitive electronics
- Limit PV capacity to 1/3 of critical loads and/or genset capacity

• OR **use curtailing controller for Inverters**

Limit to **200kW**

Expected critical load = **600kW**
Grid-Interactive PV System & Backup Engine-Generator Set “Genset”

Emergency Backup Mode with Curtailing Controller

- Limit PV capacity to \( \frac{2}{3} \) of critical loads and/or genset capacity
- Senses Inverter output, Genset output, and load demand
  - Direct connection to Inverters (brand specific), CT’s on other feeds
  - As critical loads drop (i.e., motor VFD’s), controller curtails PV output
  - Protects critical components and genset controller
- Common on mining operations

Diagram:

- Solar array
- Curtailing controller
- DC to AC converter
- ATS
- Genset 750kW
- Limit to 400kW

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Dr. Jekyll Solar vs Mr. Hyde Solar

“Build me a ground-mounted solar array”
“Make it really good, make it economical, and make it fast”

You want it good, fast, and cheap?

Pick two!
Dr. Jekyll Solar vs Mr. Hyde Solar

NYSERDA QC Inspections, 2012-2014

- Conductor label/color
- Grounding
- Protecting conductors
- Interconnection
- Bonding
- Conductor sizing
- Structural, racking, flashing
- Missing expansion fittings

National Electrical Code allows free-air wire management
Wire Management = opportunities to ensure Safety, Performance, Aesthetics!
Components are UL-listed, UV-resistant
Workmanship is secure, uniform, protected (both wires and people)
Basic electrical workmanship and code requirements
Three major components of a solar array are the Modules, Inverters, and Racking.

Module Selection Criteria

- **Purpose**
  - Industrial grade or architectural features

- **Physical requirements**
  - Corrosion resistance, wind rating, size, weight

- **Quality attributes**
  - Warranty, performance, country of origin
  - Manufacturer financial strength

"Bankable", "Tier-1" modules

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Inverter Architecture

CENTRAL

INVERTER
Inverter Architecture

CENTRAL

STRING

INVERTERS
Inverter Architecture

Selection Factors
- Variability of tilt and azimuth
- Cost vs production (First Cost vs Life-Cycle Cost)
- Others

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System Configuration: Central/String Inverters

- DC (up to 600V)
- AC (building voltage)

Central Inverter

ON Switch

600 Volt wiring

AC panel

AzimuthEnergy.net
System Configuration: Central/String Inverters

SWITCHED OFF

- **DC** (up to 600V)
- **AC** (building voltage)
- De-energized

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Central Inverter

600 Volt wiring

Switch OFF

AC panel
System Configuration: Micro-Inverters

Micro-inverters

Switch
ON
AC panel

DC (less than 40V)
AC (building voltage)
System Configuration: Micro-Inverters

SWITCHED OFF

Micro-inverters

Switch OFF

AC panel

DC (less than 40V)

AC (building voltage)

De-energized
Array Footprint – 10,000 square feet for 100 kW
Cost range $250,000 to $275,000
No rooftop equipment
*Offset 100% of electricity for 1-story office building covered with solar panels*
Roof Layout & Project Details

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4’ to 6’ around the roof edge
4’ to 6’ around the roof edge
Rooftop unit
Roof Layout & Project Details

4’ to 6’ around the roof edge
Rooftop unit requires 4’ clearway
Roof Layout & Project Details

4’ to 6’ around the roof edge
4’ pathway to all equipment
Rooftop unit requires 4’ clearway
Roof Layout & Project Details

- 4’ to 6’ around the roof edge
- 4’ pathway to all equipment
- Rooftop unit requires 4’ clearway
- Ventilation pathway for any dimension over 150’
Roof Layout & Project Details

THE REAL WORLD …

- Multiple rooftop units, placed closest to the required use
- Various vent stacks and roof drains
- Tall, ornamental parapet wall on the south side
Roof Layout & Project Details

100kW reduced to 50kW, but …

• Maintenance crew happy because they can service all the equipment
• Emergency responders happy because they can move around on the roof

BUILD NEW CONSTRUCTION “SOLAR READY”!
Design Considerations: Racking

Ground

- ~ 200sf / kW DC “inside the fence”
- Easier to service and maintain
- Good if no roof space available
- Good if you’ve got extra land
- More visible
Design Considerations: Racking

Roof
- ~ 100sf / kW DC (small array, large roof) to ~200sf / kW (Large array, large roof)
- Less expensive than ground mount
- Easier to connect to building systems
- Ballasted limited to 5°-10° slope
- 3psf (attached) to 10psf (ballasted)
## Design Considerations: Racking

### Ground
- Good if no roof space available
- Good if you’ve got extra land
- Easier to service and maintain
- More visible
- ~ 200sf / kW DC “inside the fence”

### Roof
- Less expensive than ground mount
- Easier to connect to building systems
- Ballasted limited to 5°-10° slope
- 3psf (attached) to 10psf (ballasted)
- 100-200sf / kW, depending on roof

### Fixed Tilt
- No moving parts
- Lowest cost
- Less space for same kW capacity
- Virtually no maintenance
- Delivers lower-cost energy except where it is very sunny

### Tracker
- More energy for same kW capacity
- More consistent power throughout the day
- May produce lower-cost energy in very sunny locations
- “Cool” factor
- Only a ground mounted system
- *Opinion – not for Illinois projects*
Design Considerations: Tilt Angle

**PROS**
- More power capacity per area
- Less ballast required
- Lower dead load weight

**CONS**
- Less energy per area
- Gets dirtier faster
- May void warranty
- More difficult to inspect & maintain wiring

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Design Considerations: Tilt Angle

Compromise of energy, power, roof loading, maintenance considerations

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## Design Considerations: Tilt Angle

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**PROS**
- More energy per area
- Easy to inspect and maintain wiring
- Stays cleaner and easier to wash

**CONS**
- Less power per area
- Heavier roof loading
- Layout more difficult due to spacing
Dual-Purpose Systems
Summary

- Solar-PV can be a valuable benefit for your wastewater agency
  - Financial: reduce energy expense, manage risk
  - Talent pool, marketing & PR
  - Lead as a steward of the environment
- Can be easily added to existing building or included in new construction
  - Depends on financing options
- Best outcomes
  - Careful planning
  - Experienced engineering
  - Team approach
- Not all solar arrays are created equal
  - Lots of variables
  - NOT rocket science, but does require QC and good workmanship
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