Putting it all together
1. Solar case studies
2. Design exercises
Solar case studies
Our first case study is a new construction project located in La Jolla, CA. The project type is a laboratory and the goal of the client was to build the most sustainable research building in the world.

Project completed November 2013
2016 AIA COTE Top Ten winner

More info on case study: http://www.aiatopten.org/node/495
The zero energy building has a 481.3 kW solar PV system, with an estimated production of 845,429 kWh.

Here we can see the southern and western facades with the solar PV system facing south, tilted at the angle of the roof.
Here we can see in the diagram the typical baseline energy budget for a laboratory (outer dotted circle) and the target energy budget determined by the architect (inner dotted circle).

The following measures were taken to cut the energy load down to the target.
The initial energy reduction was through architectural solutions, like sunshades and building orientation. This cut the energy load by 7%.
Next, additional energy savings were achieved through improvements to HVAC and lighting systems.
Then finally, by changing the culture of the research and laboratory, the design was able to save 73% more energy than the baseline design.
Case Study - J. Craig Venter Institute

Total Building Energy Cost Performance

Here is a table from the LEED energy report that compares the baseline and proposed energy costs.

We can see the baseline design, according to ASHRAE standards, puts the building at $123K in annual electricity costs. With the efficiencies previously discussed, the proposed design cuts the energy costs down to $54K annually.

With the addition of the solar PV system, the building achieves its zero energy status, and has a surplus of $17K annually.

That’s $141K under the baseline design!
ANIMATION SLIDE

Here in the building section, we can see the PV panels on the roof. During the initial roof design, considerations for solar PV were taken into account. Here we can see the roof is tilted to allow for maximum solar generation.

The panels over the working space cover the entire roof, while the panels over the atrium are spaced to allow for daylighting.
Case Study - J. Craig Venter Institute

Photo credit: Nick Merrick
Our second case study is an adaptive reuse project located in Grand Junction, CO. The federal building is comprised of court rooms and general office space.

Project completed February 2013
2014 AIA COTE Top Ten winner

For more information on the case study: http://www.aiatopten.org/node/367
The zero energy design includes two solar PV systems. The first PV system is suspended on a rooftop canopy, which provides shade and open space for occupants to utilize. The second is mounted on the original roof.

http://www.aiatopten.org/node/367
Here is an energy use summary from the LEED energy report. Here we can see with the efficiencies included in the proposed design, along with the solar PV system, the building will have an excess of 10K kWh per year.

The two solar PV systems comprise 123kW of capacity, with an estimated production of 173,608 kWh.
Here is a table from the LEED energy report that compares the baseline and proposed energy costs.

We can see the baseline design, according to ASHRAE standards, puts the building at $31K in annual electricity costs. With the additional efficiencies, the proposed design cuts the energy costs down to $11K annually.

With the addition of the solar PV system, the building achieves its zero energy status, and has a surplus of $731 annually.

That’s $32K under the baseline design!

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Baseline Cost</th>
<th>Proposed Cost</th>
<th>Total Energy Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>$2,951.4</td>
<td>$0</td>
<td>$-731</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Totals</td>
<td>$2,951.4</td>
<td>$0</td>
<td>$-731</td>
</tr>
</tbody>
</table>

Baseline process energy costs as percent of total energy costs (%): 9.35

Energy cost savings: 102.32%

EA Credit 1 points documented: 19

$32,281.75 under baseline
Case Study - Wayne Aspinall Federal Building

North Elevation after restauration and installation of photovoltaic array at canopy

North Elevation prior to restoration

Photo credit: Kevin G. Reeves
Here is an example of a new construction project, with solar PV, but was not planned to be a zero energy building.

Completed 2013
2016 AIA COTE Top Ten winner

Supermarkets and food service use more energy per square foot than any other commercial building sector and are more than twice as energy-intensive as office buildings and schools, primarily due to systems used to ensure safe fresh food. H-E-B’s energy conservation allows them to pass on savings in the form of lower prices to their customers, who come from a broad spectrum of income levels and demographics.

H-E-B at Mueller slashed its energy use by an estimated 64% over the grocery store national median while achieving a more comfortable customer environment. This was accomplished through a whole-system approach, reaping multiple benefits from single design moves

http://www.aiatopten.org/node/489
To understand the savings H-E-B could achieve, the team first looked at where grocery store operations use energy. Of all utility costs (including truck fuel, landfill fees, water, gas, and electricity), store electricity is by far the biggest expense. Breaking store electricity down into end uses, the biggest portion goes to refrigeration (typically 50% for grocery stores), then refrigerated-case anti-sweat devices and other equipment, HVAC, and then lighting. Understanding that HVAC and refrigeration together make up the majority of a store’s energy load, the team determined that addressing this would have the most impact on reducing overall store energy use. Demand-side efficiency measures were recommended, including high-efficiency fans and ductwork, a chiller plant with cooling tower, radiant cooling and heating, and desiccant dehumidification of outside air. These provided the best combination of energy efficiency and replicability to any H-E-B site.

An innovative propane refrigeration system with zero ozone depletion potential and low global warming potential allows for 95% less refrigerant than conventional systems. A 169 kW roof-mounted solar photovoltaic system generates enough electricity to power all the store’s lighting.

Design phase energy models estimated that the store would exceed the 2013 2030 Challenge target of 60% reduction.
Case Study: H-E-B at Mueller

**Solar PV System Capacity:** 169 kW
**Annual kWh Production:** 234,800 kWh
Here is a table from the LEED energy report that compares the baseline and proposed energy costs.

We can see the baseline design, according to ASHRAE standards, puts the building at $274K in annual electricity costs. With the additional efficiencies, the proposed design cuts the energy costs down to $217K annually.

With the addition of the solar PV system reduces the annual electricity costs to $200K.

That's $73K under the baseline design, showing that even though the PV system is not offsetting 100% of the electricity use, the system can still provide significant savings to the building owner.
Here is a residential case study in Charleston, SC.

The home is 2,208 sf and has a 5.886 kW solar PV system.
Case Study: Residential, Charleston, SC

Here is a copy of their utility bill. Here we can see the number of kWh this home pulled from the grid (517 kWh) and the number of kWh the solar PV system sent back to the grid (-690 kWh). This left the homeowner with a negative balance that will be rolled over to the next month. We can also see the homeowner still has a charge on their bill, even though they have credits to roll over. Many utilities have a minimum charge associated with the net metering tariff to account for the use and maintenance of the grid. Minimum charges are typically $5-10 per month.

Note: not all utilities will show the imports and exports of the solar system separately. Some will just show the net kWh, and you will need to contact the utility to receive the imports/exports.
Here is another excerpt from the utility bill. It shows the breakdown of kWh usage from the grid and the exports from the solar system.

We can see the homeowner used 517 kWh from the utility grid, likely in the evening when the solar system was not producing. During the day, the system exported 690 kWh hours. The net usage was -173 kWh, meaning the homeowner accumulated a credit. The homeowner accumulated a credit in the previous month as well, so the current credit, or “excess energy” is -818 kWh.

These credits can be used by the homeowner in later month when the solar system does not produce as much kWh as the homeowner pulls from the grid.
Case Study: Residential, Charleston, SC

Third Party Notification Program is a safety net that allows others to be notified of a situation that may affect your energy service, especially during emergency or critical conditions. This program gives you the option of naming another (such as a friend, relative, neighbor, clergy or social agency) to receive a copy of any disconnection notice sent to you. The third party is not responsible for paying the bill. Call 1-800-291-7234 to enroll.
Design Exercises
Exercise 1: Site Layout

Sketch Exercise
1. What areas will be shaded from neighboring buildings?
2. Where should the building be placed?
3. Where are the good solar sites?

Sketch exercise

**HOW TO PRESENT:**
First, introduce the site to the attendees (slide #28). Show them the 3-story existing building on the north side, 2-story existing building on the west side, a park on the east side, and potential future development, up to 3 stories, on the south side of the lot. Then, show them the two buildings that need to be sited in the lot.

Then, give the attendees 5 minutes to sketch on their worksheet:

- Where the buildings should be located
- Where should the solar system be placed

When the 5 minutes are up (or the attendees have stopped sketching), move to the next slide.
Exercise 1: Site Layout

Sketch Exercise
1. What areas will be shaded from neighboring buildings?
2. Where should the building be placed?
3. Where are the good solar sites?

ANSWER: Here is one option to maximize the area to add solar PV. First, since there is potential future the development on the south side of the building, we should block off the southern part of the lot for shade. Since the existing building to the west is across the street and only 2-stories, it will not cast shade on the lot. Further, the building on the north side will not cast any shade, since it is to the north. Now that we understand where the shade from the neighboring buildings will fall, we can place the buildings.

In this example, the buildings are placed on the north side of the lot, which opens up the middle of the lot for a car port installation. In addition to the carports, solar PV could be installed on the roofs of the buildings and on the facades.

Remember, there is more than one “right” answer.

TAKE AWAY #1: There are many factors to take into consideration when site planning for optimal solar performance, including:
• Existing neighboring buildings
• Future neighboring buildings
• Buildings on the site
• Landscaping
Exercise 1: Site Layout

TAKE AWAY #2: Remember, there are many options for solar PV installations beyond roof installations. Each of these examples are using the standard PV panel.
Exercise 2: Choose the best inverter

Example System 1
• 1 south-facing array
• 1 west-facing array
• No shade

Option 1:
Micro inverters

Option 2:
2 string inverters

HOW TO PRESENT:

Give the attendees ~5 minutes to read through the examples on their worksheet. Direct them to write down the most appropriate inverter and explain why. Then move through the following slides, read the example, have the attendees shout out their answers, and then walk them through the best options.

Example System 1
What is the best inverter for a system with multi-direction arrays, with no shade?

ANSWER: Modules facing different directions should not be placed on one string inverter, so the best options would be micro inverters for the entire system, or two string inverters, splitting the panels that face different directions.
Example System 2
What is the best inverter for a system with 2 arrays, both facing south, with minimal shade?

**ANSWER:** A string inverter alone will suffice for this example, because the arrays are both facing the same direction and there is minimal shade. If the system included arrays that faced different direction, or there was shading, then microinverters or a string inverter with DC optimizers would be needed.

Additionally, if the customer would like monitoring with panel level production, then micro inverters or a string inverter plus DC power optimizers should be used.
Example System 3
What is the best inverter for a system with 2 arrays, both facing south, with a panel shaded in the afternoon.

ANSWER: If there is significant shading it is necessary to use micro inverters or a sting inverter with DC power optimizers. If string inverter was chosen, the production of the entire string would drop during the afternoon hours when the one panel is shaded. Because both micro inverters and DC optimizers work at a panel level, the production of one panel will not affect the next. This way, only the production of the one panel will drop and not the entire string.
Exercise 2: Choose the best inverter

TAKE AWAY #1: It is important to consider the system design, possible shading, and the client’s interest in performance monitoring when choosing an inverter.

TAKE AWAY #2: There may be more than one inverter option that will work well.
HOW TO PRESENT:

Give the attendees ~3-5 minutes to draw a line from the ‘mounting method’ to the ‘site consideration’ on their worksheet. Then, go through each answer on the following slides.

There are many mounting methods for solar PV. Match the mounting method to the site consideration.
**Exercise 3:** Choose the best mounting method

<table>
<thead>
<tr>
<th>Tilted rack</th>
<th>Flat roof, concern with drilling holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pole</td>
<td>Pitched roof</td>
</tr>
<tr>
<td>Ballast</td>
<td>Flat roof, concern with additional weight</td>
</tr>
<tr>
<td>Flush</td>
<td>Parking lot or field</td>
</tr>
</tbody>
</table>

**ANSWER:** If there is a concern about additional weight on the roof, then a tilted rack (and not ballasted system) should be used.

A ballasted system will add more weight per sf to roof than a tilted rack system. In fact, a ballasted system will add 3-5 lb per sf MORE than a tilted rack system.
Exercise 3: Choose the best mounting method

- **Tilted rack**: Flat roof, concern with drilling holes
- **Pole**: Pitched roof
- **Ballast**: Flat roof, concern with additional weight
- **Flush**: Parking lot or field

**ANSWER**: Pole mounting is for parking lots, fields, and canopies
**ANSWER:** If there is a concern for drilling through the roof, a ballasted system should be considered since it requires no roof penetrations.

All other options will require penetrations.
**Exercise 3: Choose the best mounting method**

<table>
<thead>
<tr>
<th>Mounting Method</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilted rack</td>
<td>Flat roof, concern with drilling holes</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>Flush</td>
<td>Parking lot or field</td>
</tr>
</tbody>
</table>

**ANSWER:** Flush mounted systems are the most common for pitched roof, due to the aesthetics.
Exercise 3: Choose the best mounting method

Flush mounted
Tilted rack mounted
Pole mounted
Ballasted

Photo credit: NREL

TAKE AWAY: Site considerations will dictate the appropriate mounting method.
Exercise 4: Calculate area needed for PV system

How much space is needed for a 10 kW system?

**Example Panels:**
- Silicon monocrystalline
- 345 watt/panel
- 77" x 39" or approx. 21 sf/panel

**Step 1: Convert kilowatts to watts**

\[
10 \text{ kW} \times 1,000 = \text{Watts}
\]

**How to Present:**

Introduce the exercise:

Next, let’s run though an exercise to calculate the area needed for a PV system using simple math. You can use the known variables provided by the module manufacturer to determine the approximate area needed for a photovoltaic array. By knowing the dimensions and the capacity (Watts) of the proposed modules, simple math will give you the approximate wattage per square foot of roof area which the array will occupy. You can determine the total area needed for the array in three steps.

Then, go through the three steps. The first step is an animation:

Our first step is to convert kilowatts to watts. As we know from earlier in the presentation, 1 kW = 1000 W.

The next steps are on the following slides. First, introduce the calculations and then give the attendees ~3 minutes to work through the calculations on their worksheet.
Exercise 4: Calculate area needed for PV system

How much space is needed for a 10 kW system?

Example Panels:
- Silicon monocrystalline
- 345 watt/panel
- 77” x 39” or approx. 21 sf/panel

Step 2: Determine the # of panels needed

\[
\frac{\text{System capacity (Watts)}}{\text{Watts per panel}} = \text{# of panels}
\]

The next step is to determine the # of panels needed for a 10kW system.

To do this, you will divide the system capacity (1000 W) by the Watts per panel
Exercise 4: Calculate area needed for PV system

How much space is needed for a 10 kW system?

Example Panels:
- Silicon monocrystalline
- 345 watt/panel
- 77" x 39" or approx. 21 sf/panel

Step 3: Calculate the total area needed for the array

\[ \text{Total array area} = \frac{\text{# of panels}}{\text{sf per panel}} \]

Now you will have all the information needed to calculate the total area needed for the array.

Divide the # of panels by the square footage per panel, and this will give you the total array area.

HOW TO PRESENT:
Now have the attendees perform the calculations on their worksheet (if they have a smartphone or computer with them). Then go through the answers on the following slides.
Exercise 4: Calculate area needed for PV system

How much space is needed for a 10 kW system?

Example Panels:
- Silicon monocrystalline
- 345 watt/panel
- 77” x 39” or approx. 21 sf/panel

**Step 1: Convert kilowatts to watts**

\[
10 \text{ kW} \times 1,000 = 10,000 \text{ Watts}
\]

First step is to convert the system capacity from kilowatts to watts:

**ANSWER:** 10 kW x 1,000 = 10,000 Watts
How much space is needed for a 10 kW system?

**Example Panels:**
- Silicon monocrystalline
- 345 watt/panel
- 77" x 39" or approx. 21 sf/panel

**Step 2: Determine the # of panels needed**

\[
\frac{10,000}{345} = 29
\]

System capacity (Watts)  \( \div \) Watts per panel \( \frac{\text{# of panels}}{} \)

The next step is to determine the # of panels needed for a 10kW system.

**ANSWER:** To do this, you will divide the system capacity (10,000 W) by the Watts per panel (345 W), and you will get 29 panels.
Exercise 4: Calculate area needed for PV system

How much space is needed for a 10 kW system?

**Example Panels:**
- Silicon monocrystalline
- 345 watt/panel
- 77" x 39" or approx. 21 sf/panel

**Step 3: Calculate the total area needed for the array**

\[
\begin{align*}
29 \times 21 &= 609 \\
\text{# of panels} \times \text{sf per panel} &= \text{Total array area}
\end{align*}
\]

Now you will have all the information needed to calculate the total area needed for the array.

**ANSWER:** Multiply the # of panels (29) by the square footage per panel (21), and this will give you the total array area, which for this system is 609 square feet.

**Remember:** you also need to account for required pathways and clear perimeter
Exercise 5: Calculate dead load

How much dead load will the same 10 kW system add to the roof?

**Racking only**

\[
\text{sf} \times 2-4 \text{ lbs/sf} = \text{Dead load}
\]

Example system:
- 10 kW
- 29 panels
- 609 sf

**HOW TO PRESENT:**
Introduce the calculations for determining the dead load of racking only and ballast mounted systems (slides 46-47). Then give the attendees ~2 minutes to perform the calculations on their worksheet.

Let's use the same system from exercise 4 to calculate the dead load for PV system.

For a racking only system the load will be approximately 2-4 lb/sf, so you will multiply the sf of the system by 2-4 lbs/sf.
Exercise 5: Calculate dead load

How much dead load will the same 10 kW system add to the roof?

**Ballasted mounted**

\[ \text{sf} \times 5-9 \text{ lbs/sf} = \text{Dead load} \]

For a ballasted mounted system the load will be approximately 5-9 lb/sf, so you will multiply the sf of the system by 5-9 lbs/sf.

Now direct them to complete the calculations on their worksheet.
Exercise 5: Calculate dead load

How much dead load will the same 10 kW system add to the roof?

Racking only

\[
\text{609 sf} \times 2-4 \text{ lbs/sf} = 1,218 – 2,436 \text{ lbs}
\]

Dead load

**ANSWER:** When you multiply 609 sf by 2-4 lbs/sf, you will get 1,218 – 2,536 lbs
**Exercise 5: Calculate dead load**

How much dead load will the same 10 kW system add to the roof?

**Ballasted mounted**

\[
\text{609 sf} \times 5.9 \text{ lbs/sf} = 3,045 - 5,481 \text{ lbs}
\]

**Dead load**

**Answer:** When you multiply 609 sf by 5.9 lbs/sf, you will get 3,045– 5,481 lbs

**Take Away:** The dead loads for PV systems are easy to quickly calculate and can vary greatly between mounting types