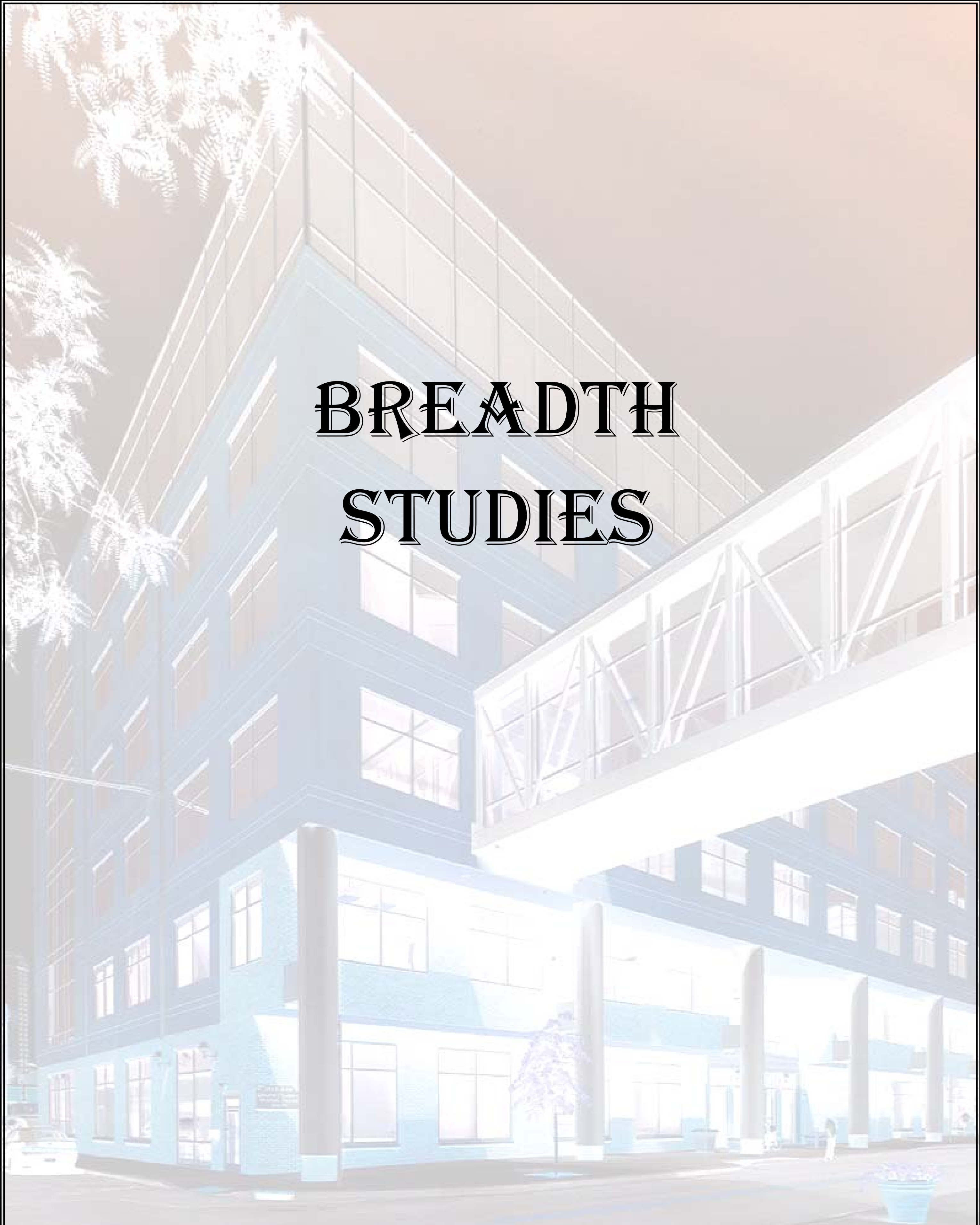
Breadth Studies



Photovoltaic Design:

One of the most prevalent approaches to making a building "green" includes the use of photovoltaic (PV) cells. PV cells can be utilized either as panels on the roof or as a "skin" attached to the façade. There are various approaches to using the façade of a building to collect solar energy. One such approach was developed by Conserval Engineering Inc. Their product, Solar Wall PV/T, combines the effects of PV's with thermal panels. The thermal panels cool the PV panels by removing the "waste" heat and using it for practical heating purposes. This increases the efficiency of the system while decreasing greenhouse gas emissions.

Atlantis Energy has created similar solar products. The first, SUNSLATES, are electric tiles that may be attached to the roof or walls of a building. These slates create an aesthetic feel by reproducing the look of slate yet generating 10.07W/sq. ft. The next product is a building integrated photovoltaic (BIPV). Atlantis produces BIPV's as glazing units.

If PVs are to be applied to the roof, the most common approach is to use panels. One of the main producers of PV roof panels is BP Solar. They offer products manufactured with either multi-crystalline or monocrystalline solar cells. Monocrystalline panels are slightly more expensive yet offer a higher efficiency than multi-crystalline panels.

After considering the location of the Wilkins building, it was decided to use roof-mounted PV panels. In a downtown location, PVs on the façade would not receive enough sunlight to generate enough electricity to offset the costs. The solar panel selected is BP Solars' 4175 model shown in Figure 12 below.

Figure 12: PV Panel

The BP 4175 uses the higher efficiency monocrystalline cells. Panel construction consists of a 3mm tempered glass panel, 72 cells in a 6x12 matrix connected in series, with a tedlar backing surface. Figure 13 lists the electrical characteristics of the panel.

Electrical Characteristics[2]	BP 4175
Maximum power (P_{max})[3]	175W
Voltage at Pmax (V_{mp})	35.7V
Current at Pmax (I_{mp})	4.9A
Warranted minimum P_{max}	166.5W
Short-circuit current (I_{sc})	5.4A
Open-circuit voltage (V_{oc})	44.0V
Temperature coefficient of I_{sc}	(0.065±0.015)%/ °C
Temperature coefficient of V_{oc}	-(160±10)mV/°C
Temperature coefficient of power	-(0.5±0.05)%/ °C
NOCT (Air 20°C; Sun 0.8kW/m^2; wind 1m/s)	47±2°C
Maximum series fuse rating	15A (S, L)
Maximum system voltage	600V (U.S. NEC & IEC 61215 rating)

Figure 13: PV Panel Electrical Characteristics

To determine the number and placement of panels on the roof, consideration must be given to the shadows cast by the parapet, roof top air handling units, penthouse, and the surrounding panels. The parapet casts a shadow 6' long so the first row of panels should not be placed closer than that. Oriented so they face south, the panels can be placed flat or inclined. To gain the full potential of each panel they will be angled at the latitude of Columbus, Ohio, approximately 40°. For simplicity of calculations, a height of 3' to match the height of the parapet was assumed. This then creates a shadow 6' long as well. Based on this, the panels should be placed as shown in Figure 14 below. To gain extra space panels were placed on the roof top units as well as the penthouse.

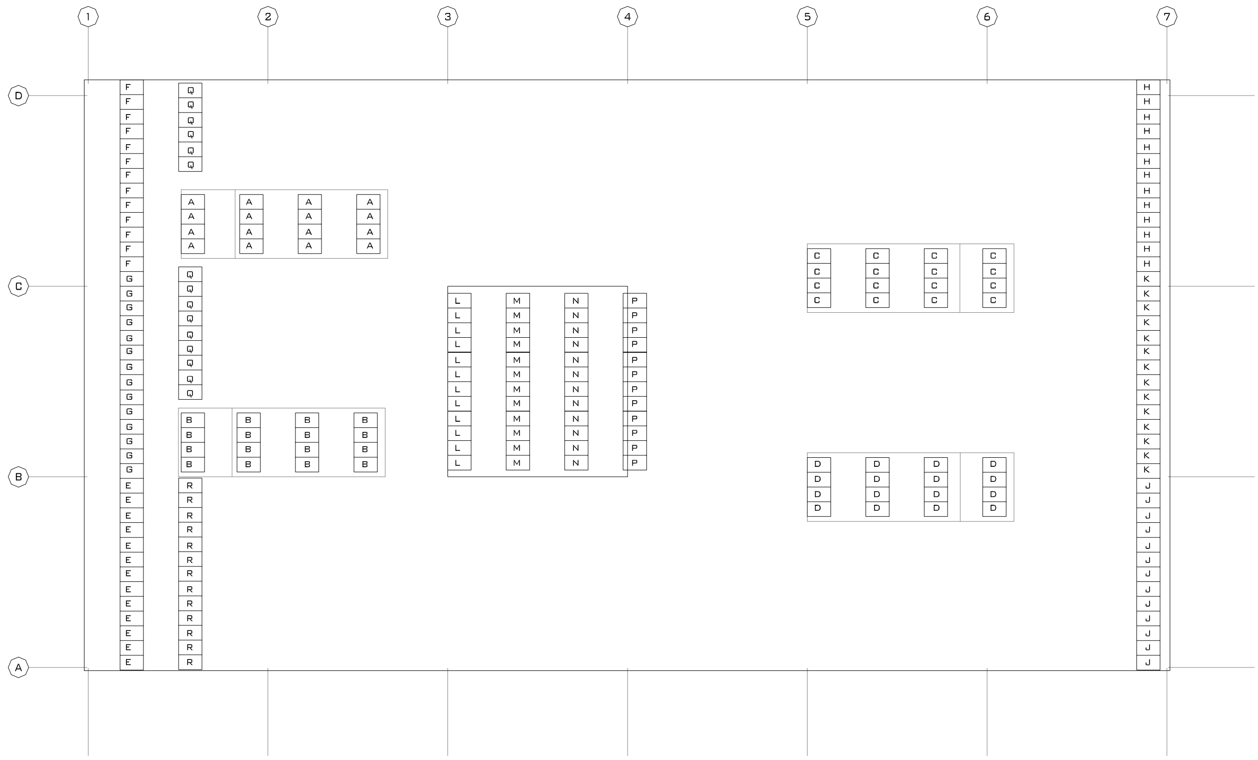


Figure 14: PV Panel Layout

This layout was chosen for several reasons. The shadow cast by the roof top units and the penthouse allow insufficient space to place any panels in the middle of the roof. Panels could be placed along either side of the roof, i.e. column lines A and D. These panels, however, are wired in series so they essentially act as resistors. If one panel does not see sun it resists the rest of the panels connected to it from collecting energy. Even if wired only to each other, these panels would only collect energy for half of the day. The gain from this is not likely to offset the cost of the PVs.

Integrating the energy collected from the panels into the building's electrical grid is relatively simple. A Sunny Boy Grid-tie Inverter can be used. The product chosen, the SB3800U (shown in Figure 15 below), allows up to 16 panels to be connected to each inverter.

Figure 15: Sunny Boy Inverter

The SB3800U is a 208V single-phase device that can supply up to 3500W. Sixteen inverters are required to accommodate the 220 panels on the roof. The distribution of the panels to inverters is designated in Figure 12 above; each letter (A-H, J-N, and P-R) goes to an inverter. Each panel will be connected to its respective inverter with #12AWG wire. The inverter connects to the panel boards with #12AWG wire as well. Panel boards 6AA and 6B are both open, so 8 inverters will be placed on each. From the panel boards, the electricity will be sent through transformer #6 to panel LP6 and back to the main distribution room.

Assuming each panel collects for 6hrs/day, 175W per panel, with an inverter efficiency of 95%, the total output would be 220 KWH/day. This is a savings of almost $20/day or $7,300/yr. For a building the size of the Wilkins building, this will not be a huge savings. However, this will also prevent roughly 100,000lbs/yr of carbon dioxide from being released into the atmosphere.

Construction Management:

Many different floor systems can be used in any given building. These include steel framing, one/two-way concrete slabs, and post-tensioned concrete slabs. In terms of one-way slabs with concrete framing there are two main options: concrete beams or skip-joists. As noted on page 14 concrete beams are no longer used in everyday design. More commonly used are skip-joists, also referred to as wide-module construction. It was also noted on page 14 that one of the main reasons for this is the cost and time associated with formwork. In today's market, forms are readily available for standard wide-module construction.

The first step to preformed formwork was initiated years ago. Pans were created for joists with slab spans of 24 - 36 inches on center. Most buildings do not have such high loading that a joist is needed every 2 - 3 feet. As a result, many times every other joist was blocked off. Thus, the term skip-joists came about. Today, on top of these pans, forms with a slab span of 53 – 66 inches have been developed.

This eliminates the need to block off every other joist making for a simplified installation process. These longer span forms are often referred to as wide-module pans.

The following is a more in-depth look into the cost and scheduling differences of a one-way slab framed with skip-joists verses concrete beams. First, a one-way system with concrete beams was designed for a typical bay. Each bay was divided into three equal spans then designed as t-beams. The structural redesign, using the same loadings as the skip-joist system design, results in the following member sizes:

Member	Size (in.)	Reinforcement
Beam	12x22	(7) #6
Girder	18x30	(3)#9, (4)#10

Table 13: One-Way Slab and Beam Schedule

A minimum slab depth of 4.5" is required with this system. For skip-joists, a slab of 4.5" was used as well. It must be noted that the minimum slab thickness required with skip-joists is 2.75". However, most pan systems are used with a 4.5" slab so 4.5" was used in design. If floor to ceiling height needed to be optimized it would be possible to use a thinner slab of 3" which would also lower the reinforcement requirements. As it is, both systems were considered with a 4.5" slab reinforced with #4's at 18" on center.

The typical bay designed with skip-joists consists of:

Member	Size	Reinforcement
Joist	7x14	(2) #8
Girder	16x26	(8)#10

Table 14: One-Way Slab and Joist Schedule

It can be seen that the size of members with the joists is much smaller. This has many advantages, which include a larger floor to ceiling height, a potentially shorter building if the same floor to ceiling height is maintained, or more cavity space for wiring and mechanical ducts. A slight disadvantage to using skip-joists is the increased number of joists in each bay. This creates a slightly larger amount of concrete.

When comparing concrete beams with skip-joists cost and schedule duration were compared. The advantages of skip-joists over beams can be seen quite easily in Table 15 below.

	Cost ($)	Duration (days)
Beams	1.1 million	540
Joists	1.0 million	250

Table 15: Cost/Schedule Comparisons

These estimates were determined using ICE 2000 assuming everything else is equal i.e. foundations, columns, slabs. The base material and labor cost is roughly the same. The real savings occurs from cost avoidance due to reduced construction time. Millions of dollars can be incurred in interest alone throughout the construction of a building this size. By eliminating the time of constructing plywood forms the construction time was cut in half. A quick estimate was performed for the skip-joist system using plywood forms. This resulted in an increase of roughly $690,000 with a construction time increase of 280 days making beams a more profitable solution.

From the above tables it is easy to see why skip-joists are used over beams. The immense savings in time creates a large financial savings. The sooner tenants can move in, the sooner revenue can be created to offset the cost of construction. Cost and installation times for skip-joist pans were obtained from Ceco Concrete, a supplier of forms.