

Cost/Benefit Analysis

OBJECTIVE

Make design decisions that deliver the best value to the building owner and future tenants.

- Cost benefit analysis normally clarifies the trade-offs between first costs and operating costs. Unless the owner or designer can assign a monetary value for incremental benefits such as improved comfort, productivity, or well-being, they are not normally considered.
- Examine economic consequences at all stages, starting with planning, and continuing through occupancy, maintenance, and demolition.

KEY IDEAS

- **Treat the building as a form of investment**, where the best investment scenario is probably not intuitively obvious. There will be complex trade-offs between many factors. As with any investment, cost/benefit analysis is appropriate.
- **Use cost/benefit analysis as a sales tool for energy efficiency.** Encourage the building owner, if necessary, to examine building costs over time. Energy-efficient buildings sometimes have higher first costs than more traditional designs; however, they generally have a much lower life-cycle cost.
- **Understand the owner's economic objectives before starting design.** Clarify the owner's economic horizon and financial requirements for this investment. This will set the criteria for how well your energy efficiency design strategies need to perform and to what degree these strategies may increase the building's first cost.
- **Treat amenity and comfort as a value.** Try to develop, with assistance from the owner, a value system for occupant comfort, productivity, increased building amenity due to daylighting, and other factors that are difficult to quantify. These are potential benefits from daylighting which can far outweigh energy savings in financial value. A reasonable assumption for these benefits, expressed in a dollars-per-square-foot value, can be directly included in cost/benefit analysis.
- **Gather your data.** What you generally need for energy efficiency cost/benefit analysis:
 - Characterization of the owner's investment criteria (available funds, discount rate, desired payback period, length of ownership)
 - Energy cost and escalation rates
 - Building energy performance
 - Construction costs
 - Maintenance and repair costs
 - Replacement schedule and costs

A more complex analysis may include more factors, such as financing costs, taxes, salvage costs, and more.

- **Get benefit information.** The judicious use of the proper window area, glazing type, and shading systems in conjunction with efficient lighting and controls will yield:
 - Decreased window solar heat gains
 - Decreased lighting energy
 - Decreased lighting heat gains
 - Improved visual and thermal comfort
- **Determine analysis objective.** The depth of cost information required depends on which of two typical objectives your cost/benefit analysis will target:
 - Assess consequences of a given decision.
 - Choose among alternatives.

In the first, comprehensive cost data will be required. In the second, only differential cost data are required.

INTEGRATION ISSUES

ARCHITECTURE

Using good performance simulation data with a cost/benefit analysis is the only way to review HVAC/lighting/envelope trade-offs. Added envelope and lighting features for daylighting and shading may be compensated for in first and operating cost savings.

INTERIOR

Cost/benefit analysis for daylighting design has relatively little impact on interior decisions.

HVAC

Use cost/benefit analysis to accurately examine how reductions in heat gains from the lighting and envelope system affect HVAC first costs and operating costs.

LIGHTING

Many energy-efficient lighting technologies and controls pay back quickly.

Savings prediction of daylighting technologies and envelope/lighting design strategies for daylight integration are not so clear-cut. Life-cycle cost analysis is recommended.

COST-EFFECTIVENESS

Cost effectiveness of energy-efficient design is best derived from a life-cycle analysis. Inclusion of hard-to-quantify factors such as comfort, productivity, tenant retention, and building amenity is recommended.

OCCUPANT COMFORT

An emphasis on low first cost is often at the price of future occupant comfort. Discomfort is typically a long-term expense.

Uncomfortable occupants may lead to long-term increases in operating costs due to thermostat adjustments by occupants or portable heaters and fans adding to plug loads. Complaints often lead to a high rate of tenant

turnover and costly mechanical or envelope retrofits. Uncomfortable occupants are less productive.

There are real economic benefits to occupant comfort, although they are hard to quantify. Nonetheless, some recognition of comfort should be included in cost/benefit analysis.

PROVISOS

- The ability to predict cost effectiveness is limited without actual building performance calculations, which are best done with advanced computer modeling software that includes daylighting analysis.
- True savings are impossible to predict exactly, due to major variables such as user behavior, future modifications to the building or site, important changes during construction, changes in utility rates, and lack of proper operation and maintenance.

TOOLS & RESOURCES

- **Nomographs** A quick and simplified tool for cost/benefit analysis is included here, in the pages that follow. Use this tool in the early design stages to help determine the relative impact daylighting might have for your project. If the nomographs indicate a potentially high investment benefit from daylighting, then further design refinement and more extensive cost/benefit analysis would be worthwhile.
- **Simple Payback Analysis** This is commonly performed when the building owner is interested in technologies that pay for themselves in as short a time period as possible. Payback Period equals Initial Cost of the Technology (or differential cost over its equivalent) divided by Annual Energy Savings due to this Technology. If you have access to the savings and cost information, you can easily perform this calculation yourself. A mechanical engineer's standard load calculation can provide energy information, while manufacturers can give you cost estimates. In other cases, you may not need computer analysis of performance. For example, simple payback analysis can be used to choose between two different pieces of lighting equipment, simply by using the power rating of the equipment, an estimate of how many hours per year the equipment will run, the typical electricity charge (ask local utility), and the product cost (ask a manufacturer's representative).
- **Life-Cycle Cost Analysis** This is a preferred method of cost analysis, because it takes into account the time value of money. However, it is too complex to be explained here. Check with an appropriate expert or your local utility, or consult the large array of literature available on this subject, such as the documents noted below.
- **Consultant** A detailed cost/benefit study requires specialized knowledge in both energy modeling and economic analysis. A consultant with experience in these areas is recommended for projects where the building owner's financial concerns are paramount.
- **Utility Company** Your local utility may provide design assistance or financial incentives. Many utilities have customer service educational centers equipped with rotating displays, seminars, and staff available to answer questions on specific projects.
- **NTIS** Many documents and guidelines are available from the National Technical Information Service. Write to NTIS, Springfield, Virginia 22161 for a publications list.

- **AIA** “Life Cycle Cost Analysis - A Guide for Architects” (American Institute of Architects, Washington D.C. 1977) is a useful handbook. Contact your local AIA chapter for this and any other relevant AIA publications. Or ask for a publications list from the national office: (800) 365-ARCH.
- **BOMA** The Building Owners and Managers Association offers publications on a variety of topics, including a large selection of economic materials. Request a publications list from BOMA, PO Box 79330, Baltimore, MD, 21279-0330, (800) 426-6292.
- **Computer Tools** “Building Life-Cycle Cost” program (BLCC) is available from NTIS at the above address.
- **Books** There are many titles available on cost/benefit analysis, covering the general topic as well as specific applications. Consult an architectural bookstore.

Building Control Systems by V. Bradshaw (Wiley and Sons 1985) includes a thorough treatment of economics.

Energy Management Handbook by W. Turner (Fairmont Press 1993) has an economics chapter.

CHECKLIST

1. Begin thinking about cost-effectiveness in early design. Once you have an idea of building shape and size, intended usage, floor-to-ceiling height, and possible window configuration, you are ready to do a preliminary analysis.
2. Gather necessary economic data as discussed above.
3. Use the Nomograph Tool here for a preliminary check on daylighting savings and cost-effectiveness. Use the tool to compare design alternatives under consideration.
4. Contact local utility for information on possible incentives.
5. If owner desires more exact cost/benefit analysis, contact utility for possible assistance.
6. Discuss further analysis with mechanical engineer.
7. Or, explore possibility of hiring a consultant.

If you have...

no time

1. Use the nomographs here, using default values given. Discuss results with building owner.

a little time

1. Use the nomographs here with better values for design details, energy costs, and owner’s investment criteria. Discuss results with building owner.
2. If mechanical engineer’s load software can include daylighting, calculate energy performance at an early stage (make assumptions about design details not yet resolved). Use that computed value of annual energy savings in Nomograph 4, in place of the annual savings found in the other nomographs. Discuss results with building owner.

more time

1. Perform a more exact cost benefit analysis. Locate either a source of consulting assistance or learn to do it yourself. See the list of resources on page 11-3.

NOMOGRAPH TOOL

The Nomograph Cost/Benefit Tool for Daylighting

A nomograph is a graphic way to present a formula that has several variables. Rather than doing the calculation mathematically, a nomograph user can “walk” through a diagram. This is an easy alternative to working out an equation, plus the graphic presentation nicely illustrates the relative importance of various parameters to the overall solution.

These nomographs are a preliminary tool for roughly assessing the potential impact of daylighting on the energy use of non-residential buildings. Use these nomographs to help decide whether or not daylighting makes much sense to pursue further. Or use them to make a decision between early design alternatives.

Cost/benefit analysis for energy-efficient design typically requires complex computer modeling to predict the building’s energy performance. These nomographs offer a simplified and easier alternative, because they have the computer analysis already built into them. The nomographs were developed after extensive computer modeling of a generic non-residential building. Many design assumptions had to be made for this model. Even though your project may differ significantly from this model, the results of a nomograph analysis should be reasonable, as long as your project is not a major departure from standard practice design. The computer analysis used Seattle (high latitude, predominately overcast) as the location for the generic building. Most other U.S. locations would achieve better daylighting performance, therefore many projects would find these nomograph results to be conservative.

Limitations to the Nomograph Tool

This tool will not deliver a guaranteed answer about cost-effectiveness.

This tool only takes into account the electric lighting energy reductions due to daylighting. It does not account for the beneficial reductions in HVAC cooling energy use (i.e., chiller and fan use) due to heat gain reductions from the electric lighting and window system. This will lead to a conservative estimate of cost-effectiveness. If the nomographs indicate good potential savings with daylight, then a more detailed analysis that includes the impact on HVAC first and operating costs due to daylighting should be performed.

This tool becomes less useful as design progresses. As the building develops further, greater accuracy is expected. A more detailed analysis tool, modeling the specifics of the building and including important factors left out by the nomographs, will deliver the level of information necessary to make late design decisions.

How to Use the Nomograph Tool

This is a seven step process. Your first time through may take an hour. Once you are familiar with the nomographs, you will be able to compare different design options and investment scenarios in just minutes. Each step is thoroughly explained in the pages that follow.

Use a photocopy of the worksheet provided to record values as you go. The first three nomographs are in preparation for the last four. The values from Nomographs 1-3 will be needed for the more complicated Nomographs 4-7.

Nomographs 4-6 determine savings associated with the energy use reduction due to daylighting. You can stop there if you simply want to find these numbers to compare different design strategies, for example.

Use Nomograph 7 to complete the cost/benefit calculation. This nomograph provides a range of economic information, including justifiable investment. In order to complete your study, you will need to obtain (from another source) the differential construction costs for the proposed daylighting scheme over a non-daylighted equivalent.

Nomograph Worksheet

ITEM		YOUR PROJECT	DEFAULT VALUE
1	Latitude		See list in Step 1
2	Daily Occupancy Schedule		8 am - 6 pm
3	Gross Area per Floor (ft ²)		
4	Typical Floor Shape (Width-to-Length Ratio)		1:1.5 (see Step 3)
5	Daylight Zone Depth		15 feet (see Step 3)
6	Lighting Control Type		One Step (see Step 2)
7	Illumination Level (fc)		50 (see Step 2)
8	Useful Window Ratio		0.65 (see Step 2)
9	Glazing Visible Transmittance (VT)		0.60 (see Step 2)
10	Useful Window Ratio x VT		0.39 (see Step 2)
11	Annual Hours of Occupancy		2500
12	Installed Lighting Load (W/ft ²)		1.5 (see Step 5)
13	Electricity Cost (\$/kWh)		0.09 (Ask local utility)
14	Gross Total Building Area (ft ²)		
15	Non-Lighting Electric Loads (W/ft ²) (HVAC, plug loads, etc)		3.5 (see Step 6)
16	Peak Demand Rate(\$/kwh-month)		(Ask local utility) (See Step 6)
17	Daylit Hours (%)		Find in Step 1
18	Control Effectiveness (%)		Find in Step 2
19	Dimming Factor (%)		80 (see Step 4)
20	Daylit Area (%)		Find in Step 3
21	Annual Energy Savings due to Daylight (%)		Find in Step 4
22	Daylight Peak Load Savings (%)		Find in Step 4
23	Non-Daylit Lighting Energy Consumption (kWh/ft ² - year)		Find in Step 5
24	Non-Daylit Lighting Energy Cost (\$/ft ² - year)		Find in Step 5
25	Daylighting Energy Consumption Savings (kWh/ft ² - year)		Find in Step 5
26	Daylighting Energy Cost Savings (\$/ft ² - year)		Find in Step 5
27	Annual Daylighting Energy Savings (\$)		Find in Step 5
28	Non-Daylit Peak Demand (kW)		Find in Step 6
29	Non-Daylit Monthly Demand Charge (\$/ft ² - month)		Find in Step 6
30	Non-Daylit Annual Demand Charge (\$/ft ² - year)		Find in Step 6
31	Daylit Peak Demand Savings (kW)		Find in Step 6
32	Daylit Monthly Demand Savings (\$/ft ² - month)		Find in Step 6
33	Daylit Annual Demand Savings (\$/ft ² - year)		Find in Step 6
34	Total Annual Savings (\$/ft ² - year)		Find in Step 6
35	Justifiable Investment (\$/ft ² or \$/project)		Find in Step 7
36	First Year Savings (\$/ft ² or \$/project)		Find in Step 7 (or same as line 34)
37	Payback Period (years)		10 (ask building owner) (Step 7)
38	Rate of Return or Discount Rate (%)		8 (ask building owner) (Step 7)
39	Energy Escalation Rate (%)		8 (ask local utility)

STEP 1

Determine what percentage of occupied hours will find daylight available.

■ FIRST

Find the latitude of your site, or choose closest California city:

San Diego:	32°	Fresno:	36°	Chico:	39°
Santa Ana:	33°	Modesto:	37°	Redding:	40°
Los Angeles:	34°	San Francisco:	37°	Eureka:	41°
Bakersfield:	35°	Stockton:	38°		
San Luis Obispo:	35°	Sacramento:	38°		

—> Record latitude in Line 1 of the worksheet.

■ SECOND

Estimate the typical daily schedule of occupancy (default 8 a.m. to 6 p.m.).

—> Record schedule in Line 2 of the worksheet.

■ THIRD

If you see your daily schedule on one of the curves (e.g., 9 a.m. - 7 p.m.) in Nomograph 1A, then:

- Find your latitude at the bottom and move up vertically until you intersect your schedule curve.
- Then move left and read your Annual Daylight Hours %.

—> Record Annual Daylight Hours % in Line 17 of the worksheet.

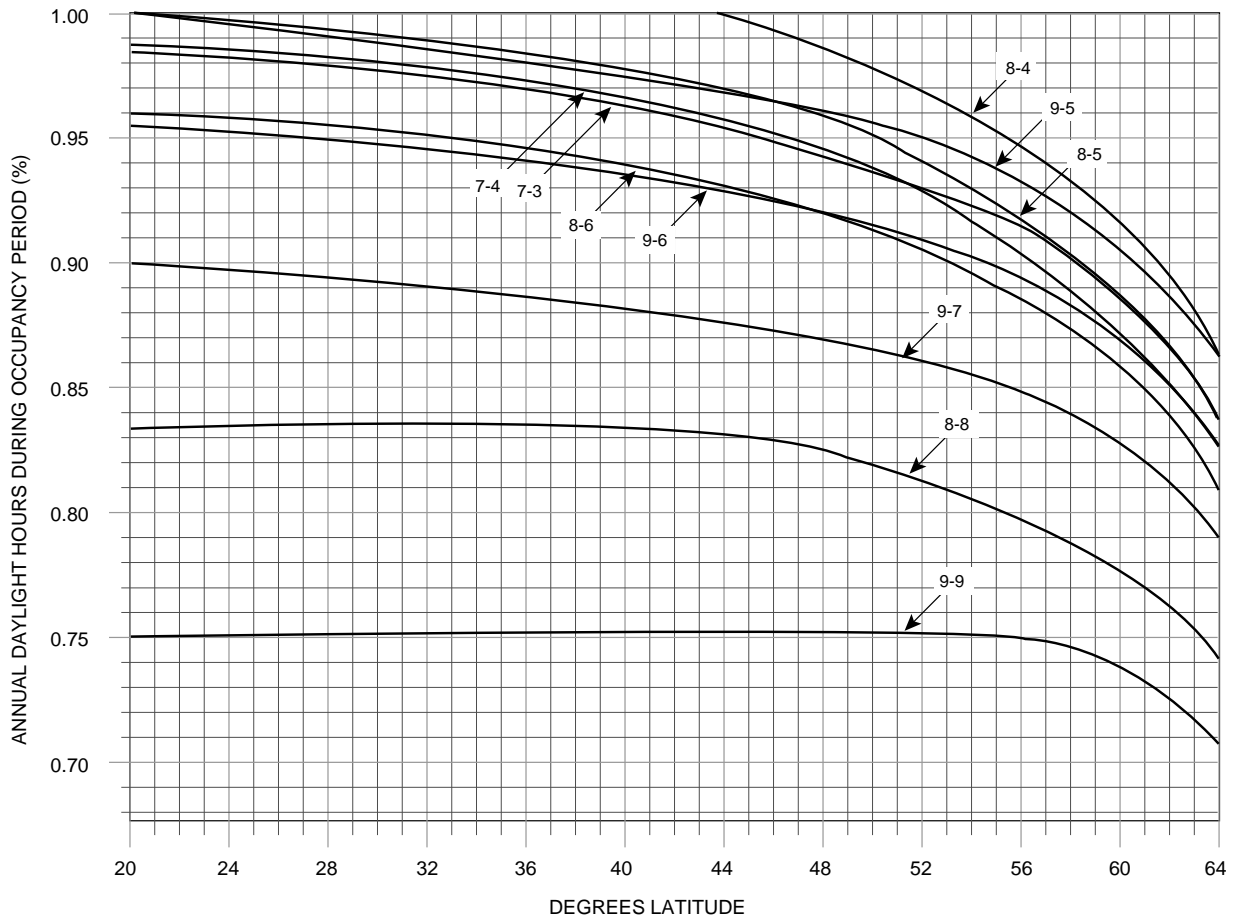
OR

If you *do not* see your daily schedule in Nomograph 1A, use Nomograph 1B.

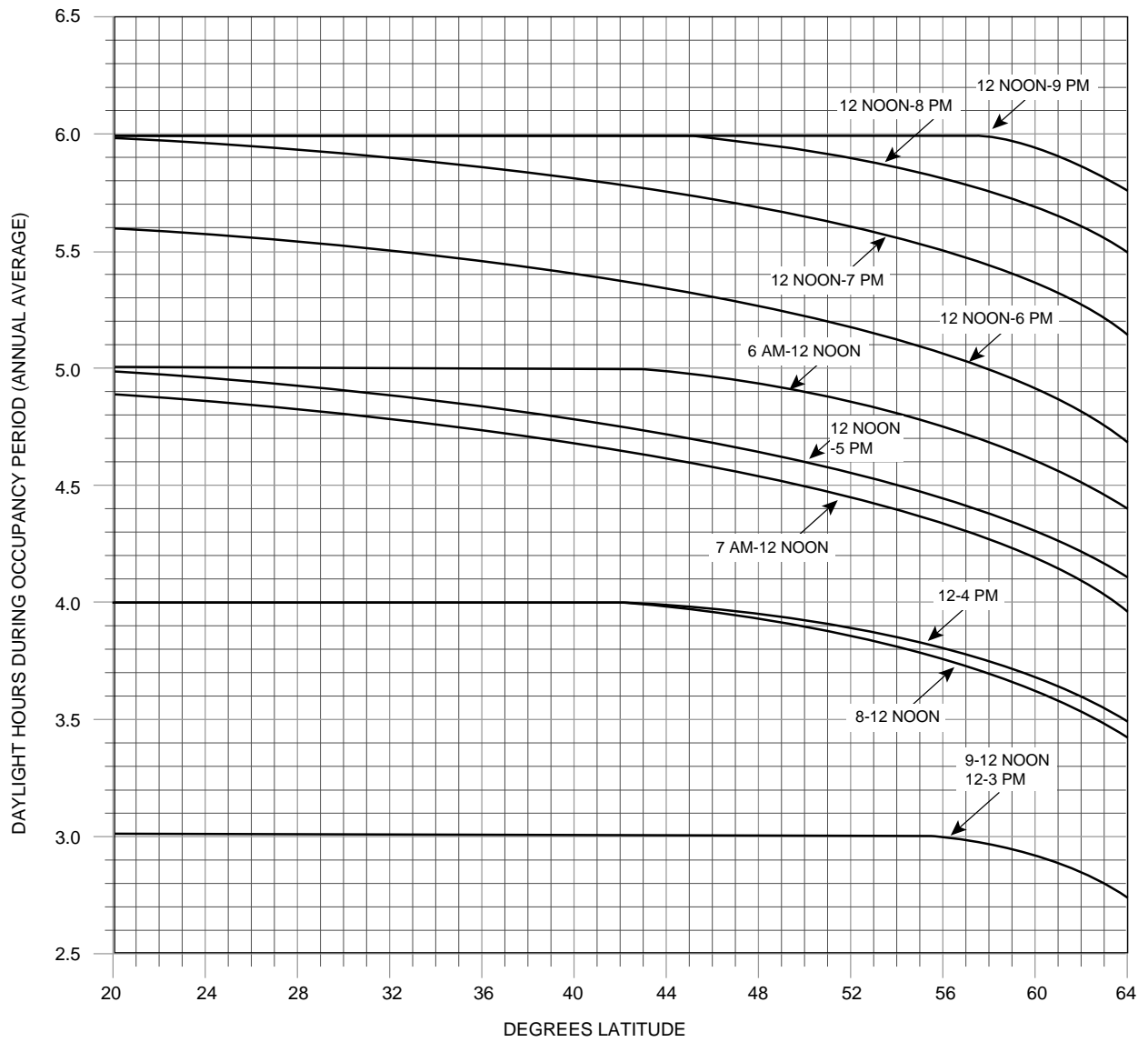
- Find your latitude at the bottom and move up vertically until you intersect your *morning* schedule curve.
- Then move left and read your Daylight Hours Annual Average.
- Repeat for afternoon schedule.
- Add both daylight hours together.
- Divide by total number of daily occupancy hours.
- Multiply by 100 to get Annual Daylight Hours %.

—> Record Annual Daylight Hours % in Line 17 of the worksheet.

Note: Daylight Savings Time has already been accounted for in these nomographs.



Nomograph 1A



Nomograph 1B

STEP 2

Find the percentage savings due to daylighting controls.

■ FIRST

Make an assumption for Lighting Control Type:

- One-Step control is least expensive, but it causes abrupt light changes and can be distracting. It is often an acceptable choice for areas with plenty of expected daylight constantly through the day.
- Continuous dimming is most expensive, but is less disturbing to occupants and tends to deliver higher energy savings.

—> Record Lighting Control Type in Line 6 of the worksheet.

■ SECOND

Make an Illumination Level assumption.

- 30 footcandles (fc) is a good ambient light level. Choose this for spaces with lower lighting needs, such as computer VDT environments.
- 50 fc is appropriate for typical desk work.
- 70 fc is a higher light level appropriate for close, detailed tasks.

—> Record Illumination Level in Line 7 of the worksheet.

■ THIRD

Calculate Useful Window Ratio for a typical office or bay:

$$\text{Useful Window Ratio} = \frac{\text{Net glazed window area above the workplane (e.g. above 30" from floor)}}{\text{Total interior window wall area from floor to ceiling}}$$

—> Record Useful Window Ratio in Line 8 of the worksheet.

■ FOURTH

Choose a Glazing Visible Transmittance (VT)

- If unknown, see the list in Section 2 (Daylight Feasibility) of these Guidelines.

—> Record Glazing Visible Transmittance in Line 9 of the worksheet.

■ FIFTH

Multiply Useful Window Ratio x Glazing Visible Transmittance (VT)

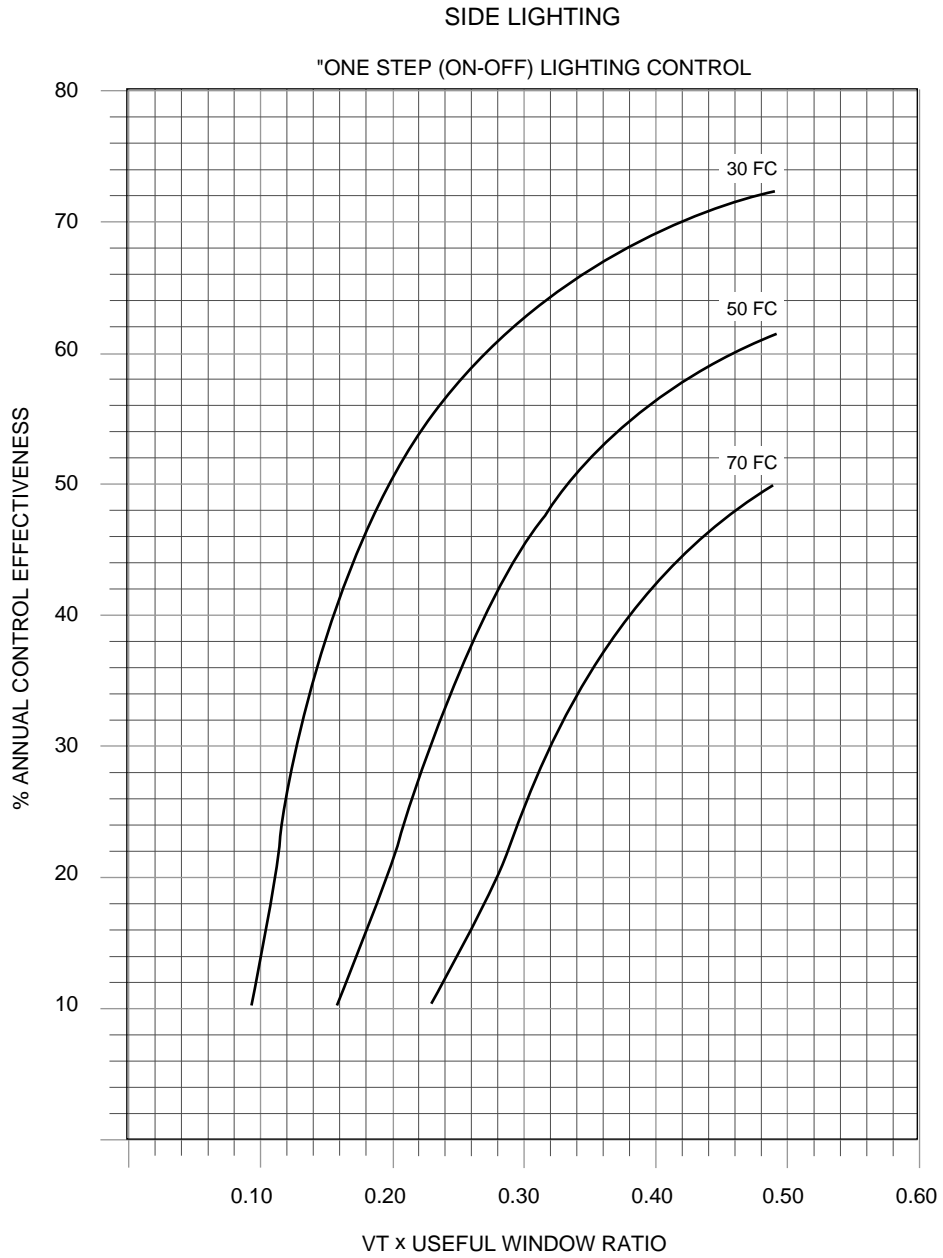
—> Record in Line 10 of the worksheet.

■ SIXTH

Use one of the nomographs to find Control Effectiveness %.

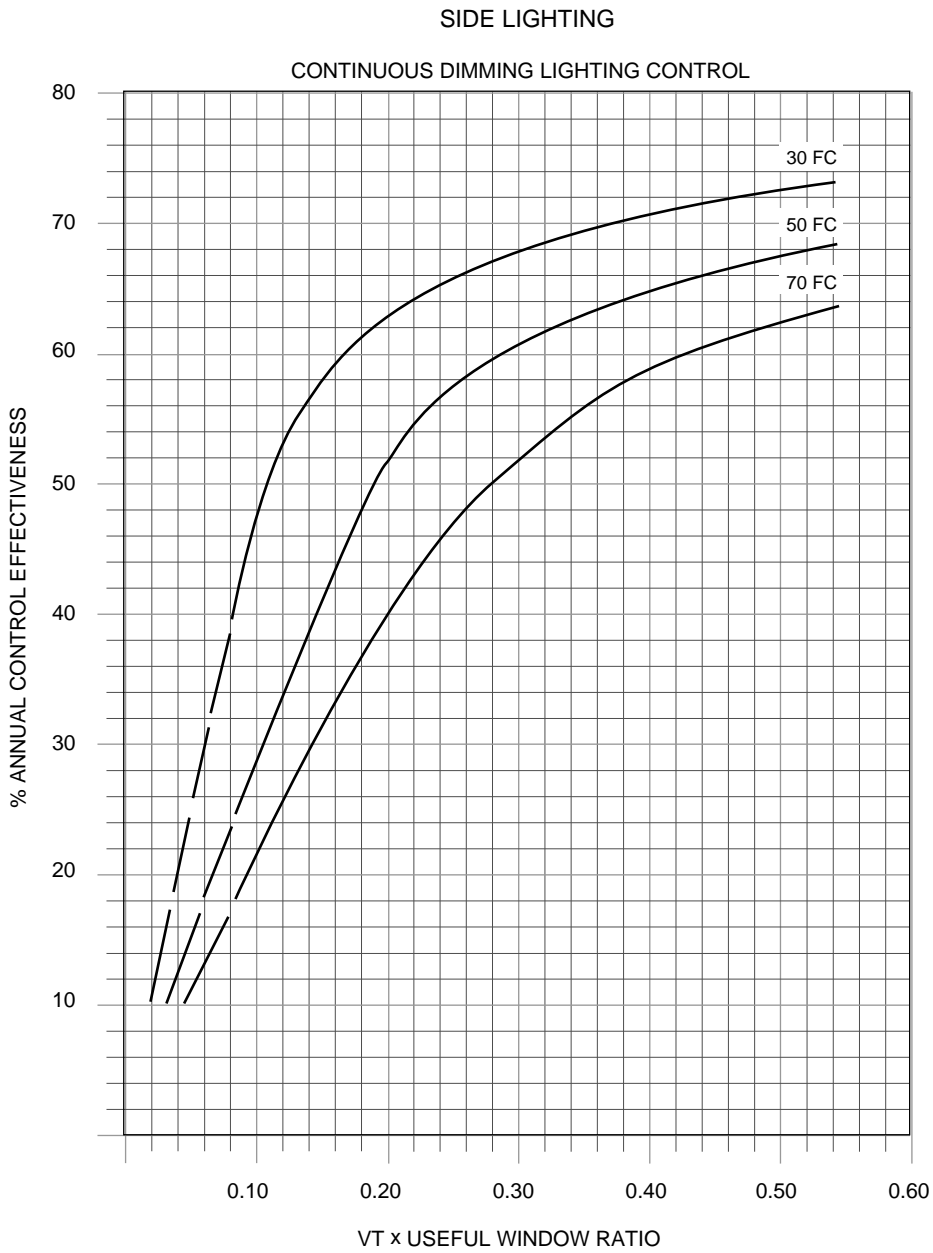
- Use Nomograph 2A if you assume One-Step controls.
- Use Nomograph 2B if you assume Continuous Dimming controls.
- Begin at the bottom with your value for Useful Window Ratio x Glazing Visible Transmittance (worksheet Line 10).
- Move up to intersect your Illumination Level curve (worksheet Line 7).
- Move left to read your Control Effectiveness %.

—> Record Control Effectiveness % in Line 18 of the worksheet.



Nomograph 2A

One-Step Controls



Nomograph 2B

Continuous Dimming

STEP 3

Find the percentage of total floor area that can be daylighted.

■ FIRST

Make an assumption of how deep your daylighted zone will be.

- If small private offices will predominate along the perimeter walls, or if window head height is 7 feet or lower, assume a 10-foot zone.
- If office layout is unknown, assume a 15-foot zone. This is a typical daylighted zone depth.
- If layout is to be open-plan with low partitions, or if ceiling is higher than 9 feet with a correspondingly high window head, assume a 20-foot zone.

—> Record Daylighting Zone Depth in Line 5 of the worksheet.

■ SECOND

If building is not a rectangular box, then calculate Daylit Area % directly from floor plans.

- For a typical floor:

$$\text{Daylit Area \%} = \frac{\text{Daylighting Zone Depth (ft)} \times \text{Total Perimeter Length (ft)}}{\text{Total Floor Area}}$$

—> Record Daylit Area % in Line 20 of the worksheet.

OR

Use one of the nomographs to find Daylit Area %.

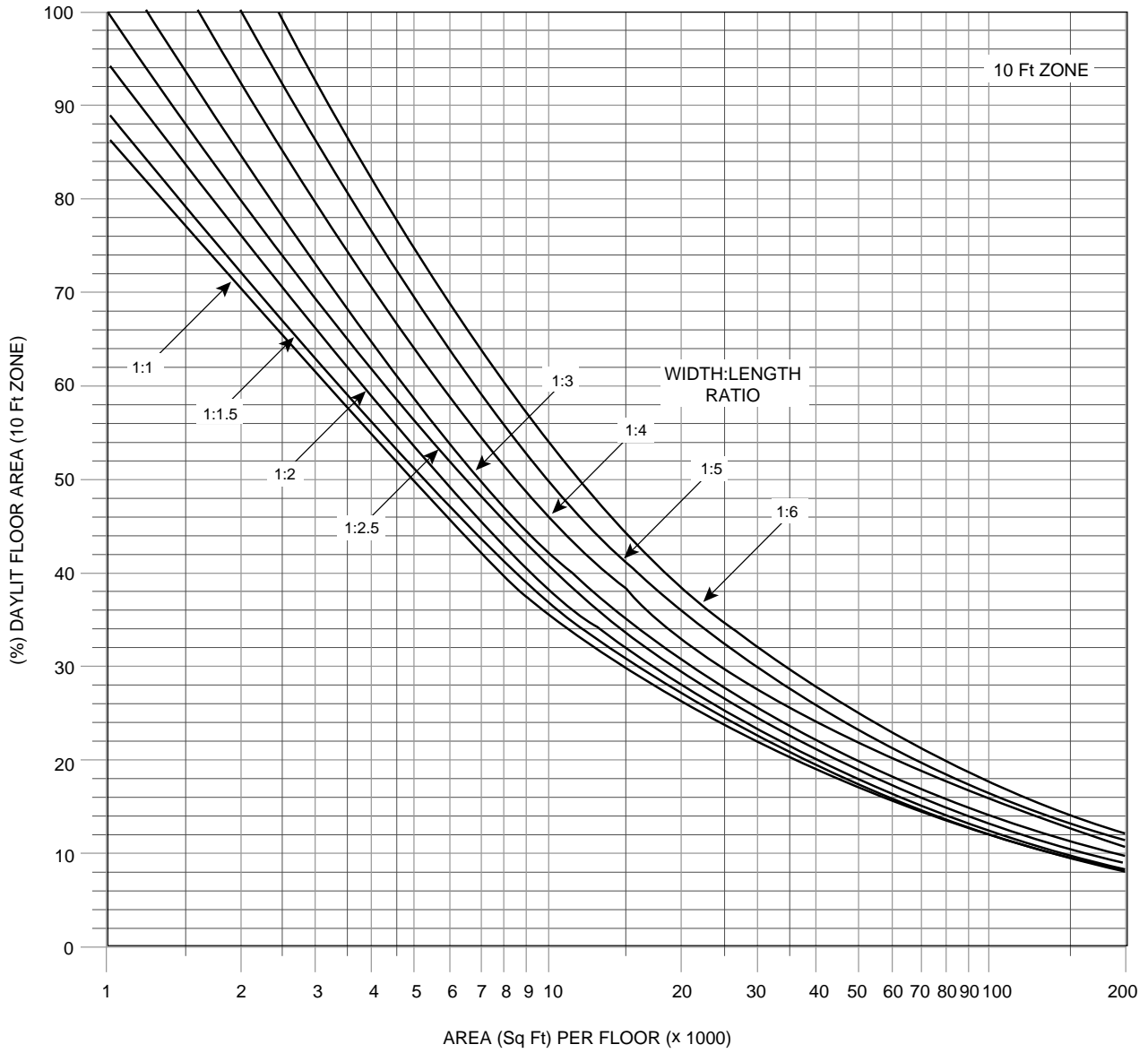
- Calculate your Width-to-Length Ratio. For example, if a typical floor is 100 ft by 150 ft, the ratio is 1:1.5.

—> Record Width-to-Length Ratio in Line 4 of the worksheet.

—> Record the square footage of a typical floor in Line 3 of the worksheet.

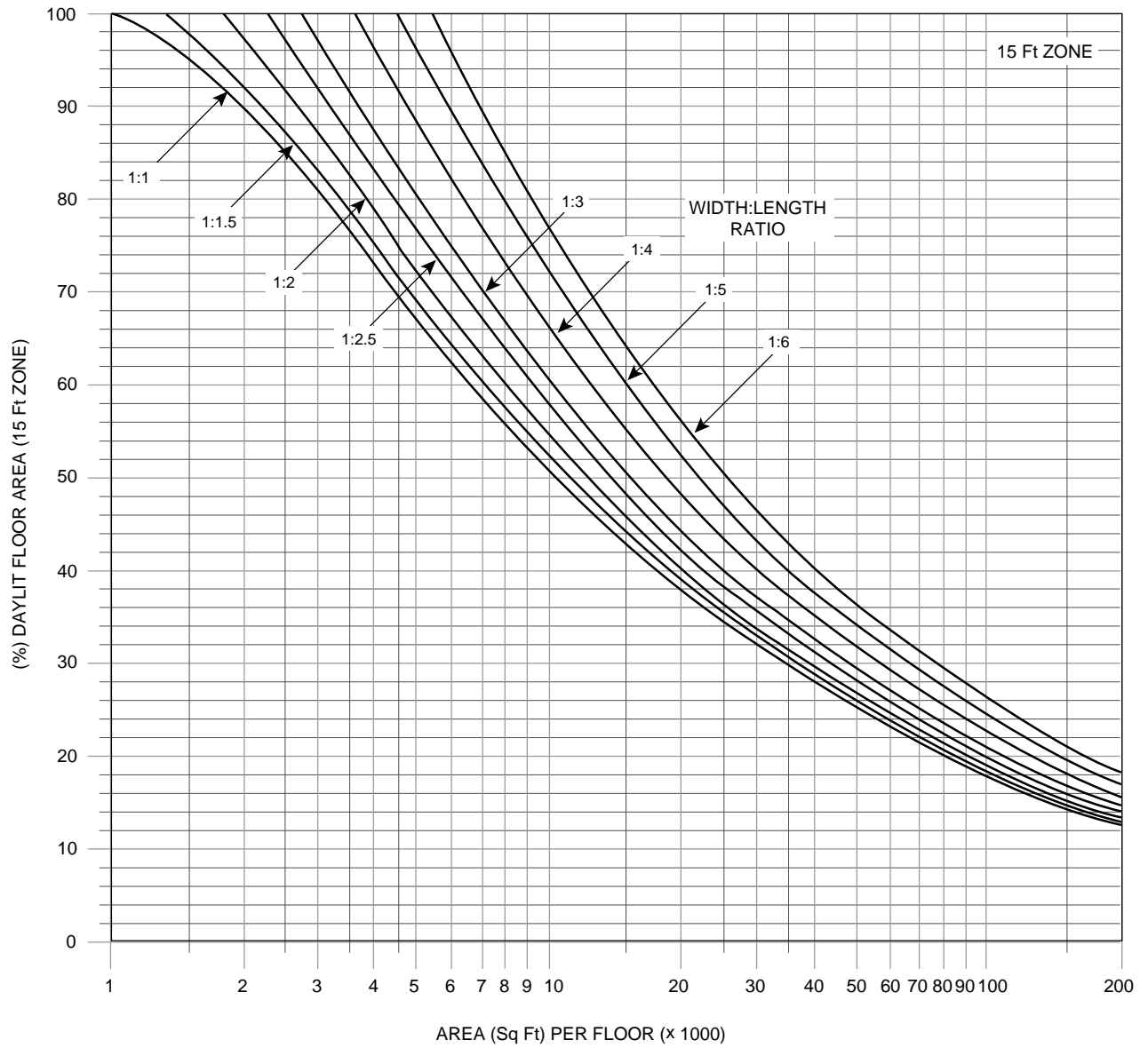
- Selecting one of the nomographs, start at the bottom with your Area per Floor (divided by 1000), move up to intersect your Width-to-Length Ratio curve, and move left to read Daylit Area %.
- Use Nomograph 3A for a 10-foot Daylighting Zone Depth.
- Use Nomograph 3B for a 15-foot Daylighting Zone Depth.
- Use Nomograph 3C for a 20-foot Daylighting Zone Depth.

—> Record Daylit Area % in Line 20 of the worksheet.



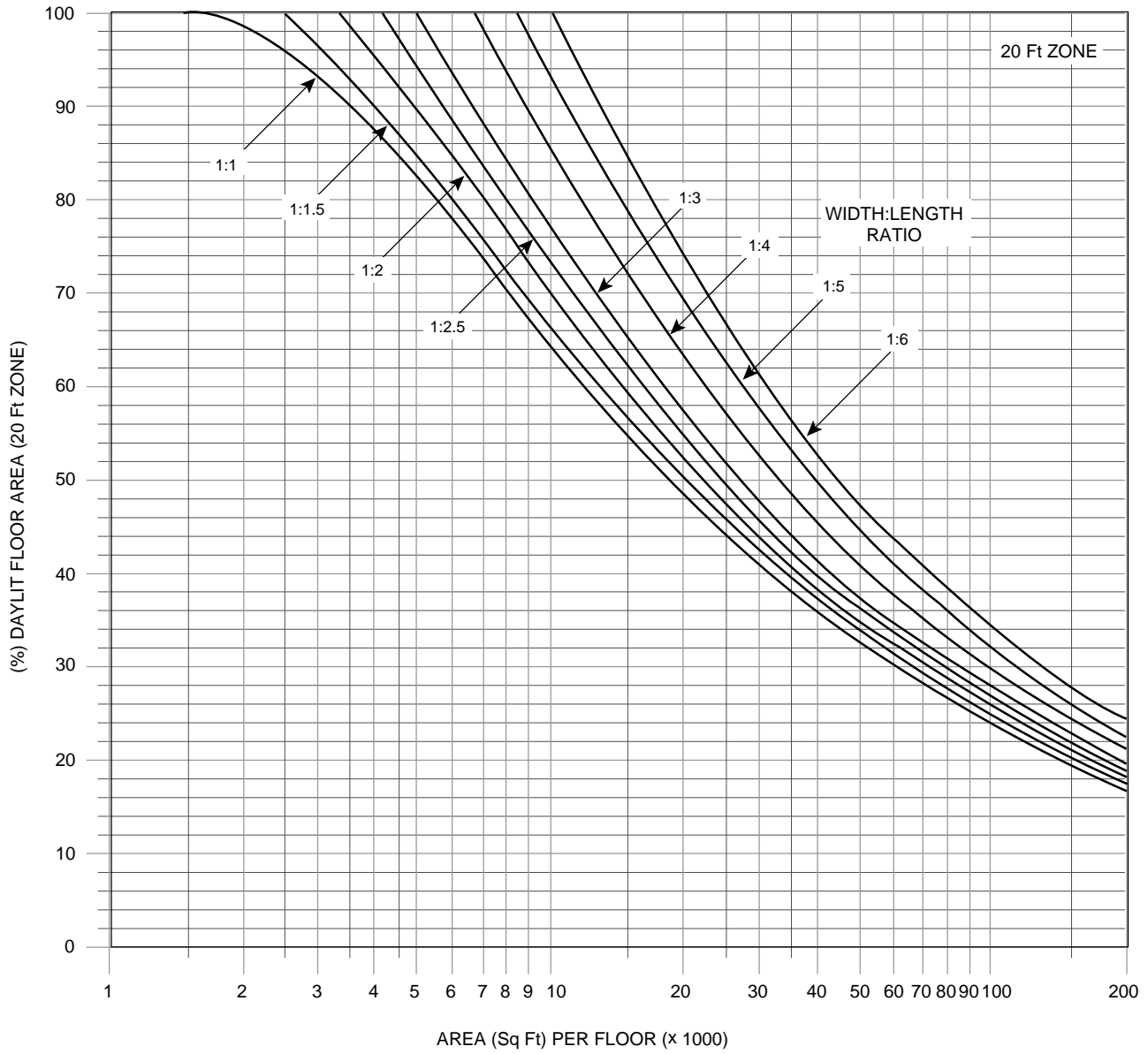
Nomograph 3A

Ten-Foot Daylighting Zone Depth



Nomograph 3B

Fifteen-Foot Daylighting Zone Depth



Nomograph 3C

Twenty-Foot Daylighting Zone Depth

STEP 4

Find the potential energy and load savings from daylighting (% reduction over a non-daylighted building).

■ FIRST

Calculate Dimming Factor—the maximum reduction of electric lighting power in daylighted zones.

- If you (or your lighting designer) know the type of control hardware and control strategy intended, then simply compute:

$$\text{Dimming Factor \%} = \left[1 - \left(\frac{\text{Minimum lighting power when fully dimmed}}{\text{Maximum lighting power when on full}} \right) \right] \times 100$$

- If controls are unknown, use the default given in the worksheet.

—> Record Dimming Factor % in Line 19 of the worksheet.

■ SECOND

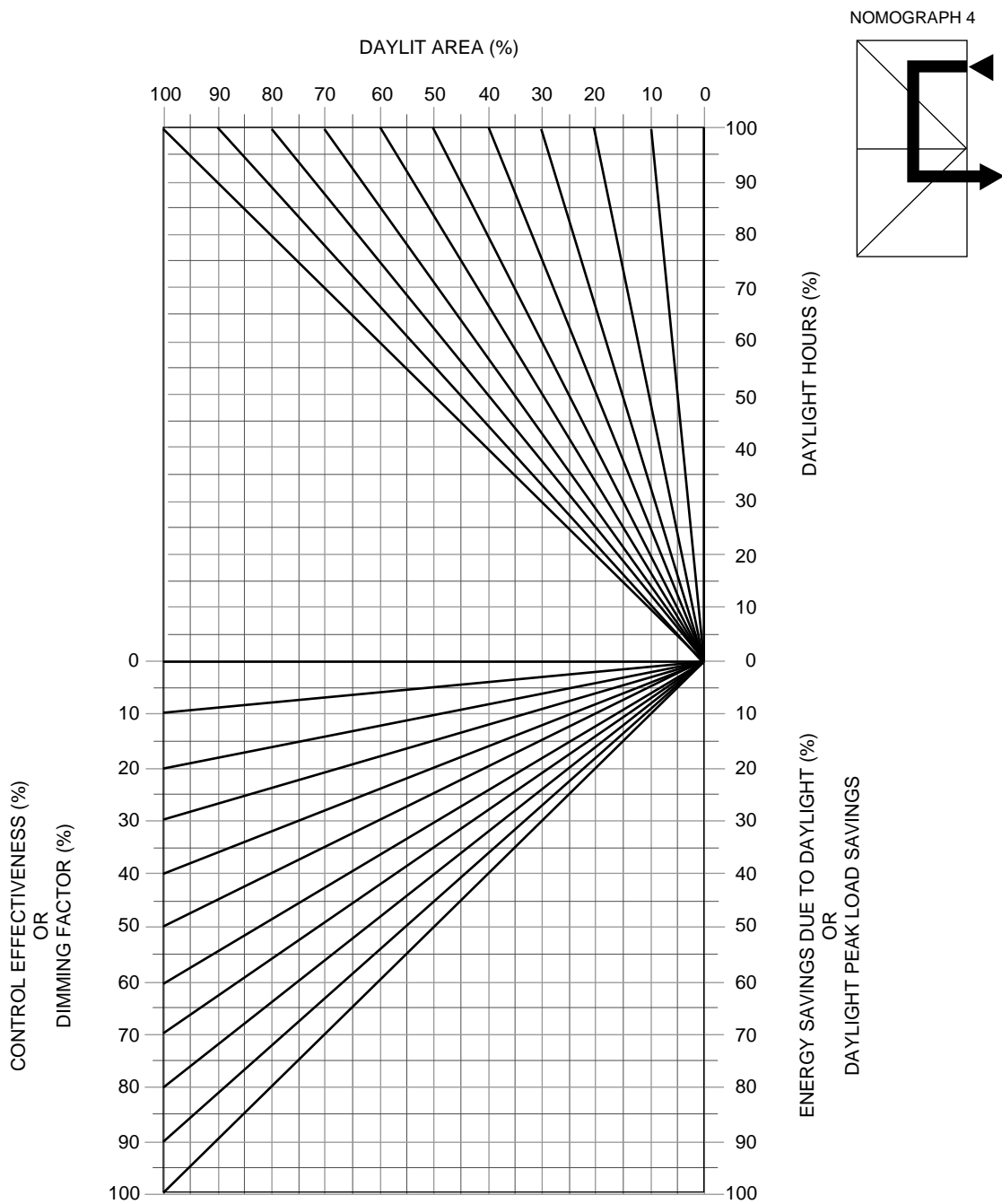
Use Nomograph 4 to find potential energy savings and load savings.

- See the key for the proper way to move through the nomograph.
- Begin at upper right at your Daylight Hours % (worksheet Line 17).
- Move left to the intersection with the diagonal line corresponding to your Daylit Area % (worksheet Line 20).
- Move down to the diagonal line for your Control Effectiveness % (worksheet Line 18).
- Move right and read your Energy Savings due to Daylight (%). This is the percentage of annual energy saved by daylighting over a non-daylighted building.

—> Record Annual Energy Savings due to Daylight in Line 21 of the worksheet.

- Repeat the first two steps.
- Move down to the diagonal line for your Dimming Factor % (worksheet Line 19).
- Move right and read your Daylight Peak Load Savings (%). This is the percentage of peak demand saved by daylighting over a non-daylighted building.

—> Record Daylight Peak Load Savings in Line 22 of the worksheet.



Nomograph 4

STEP 5

Find lighting energy and cost savings due to daylighting.

■ FIRST

Estimate Installed Lighting Load (watts/ft²), including both task and ambient lighting.

- Lighting designer can provide this information.
- Or, select from this list of Title 24 allowable lighting power densities:

office	1.5	religious	2.0
medical	1.5	auditorium, convention	2.0
grocery	1.8	restaurant	1.5
industrial (work)	1.2	retail	2.0
industrial (storage)	0.8	school	1.8

—> Record Installed Lighting Load in Line 12 of the worksheet.

■ SECOND

Use Nomograph 5 to find lighting energy and lighting costs for a *non-daylighted* building.

- Determine your Annual Hours of Occupancy by asking your client/building owner, or use the default value of 2500 hours.

—> Record this in Line 11 of the worksheet.

- Enter at upper left, as shown in the key, with Annual Hours of Occupancy (worksheet Line 11).
- Move up to intersect the 100% Daylight Hours line.
- Move right to intersect your Installed Lighting Load line (worksheet Line 12).
- Move down to intersect the 100% Control Effectiveness line.
- Move left to intersect the 100% Daylit Area line.
- Move down and read the value at your intersection with the KWHRS/FT²-YR scale. This is how many kilowatt-hours per square foot per year are required to electrically light the building.

—> Record this in Line 23 of the worksheet—Non-Daylit Lighting Energy Consumption.

- Determine your electricity cost (\$/KWH) by asking your local utility, or use the default value of \$0.10/KWH

—> Record this in Line 13 of the worksheet.

- Continue down to intersect your Electricity Cost line (worksheet Line 13).
- Move right and read your intersecting value on the Lighting Cost/Savings scale. This is the cost per square foot per year to electrically light the building.

—> Record this in Line 24 of the worksheet—Non-Daylit Lighting Energy Cost.

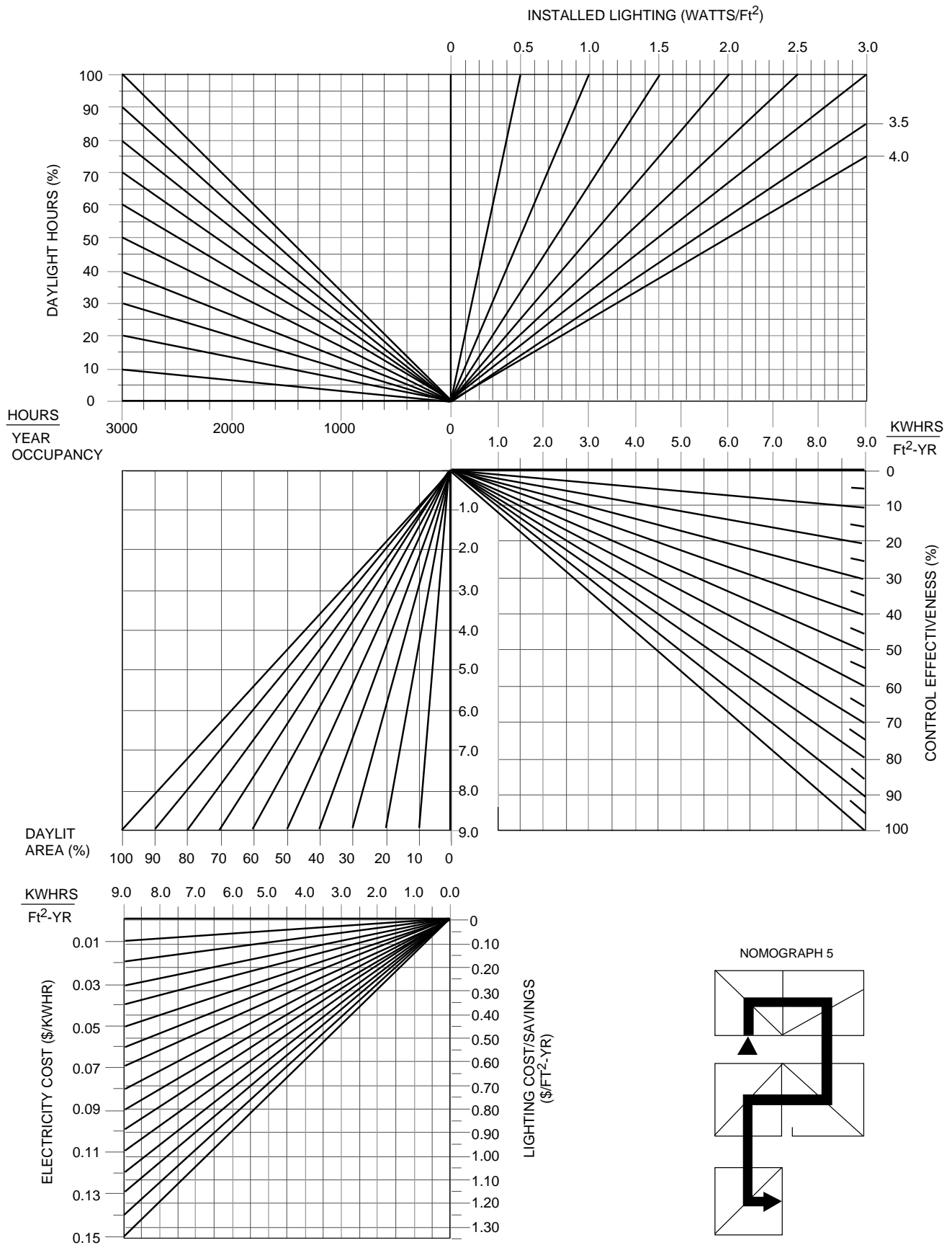
■ THIRD

Use Nomograph 5 again, this time to find lighting energy and lighting costs for a daylighted building.

- Enter at upper left, as before, with your Annual Hours of Occupancy (worksheet Line 11).
- Move up to intersect your Daylight Hours % line (worksheet Line 17).
- Move right to intersect your Installed Lighting Load line (worksheet Line 12).
- Move down to intersect your Control Effectiveness % line (worksheet Line 18).
- Move left to intersect the Daylit Area % line (worksheet Line 20).
- Move down and read the value at your intersection with the KWHRS/FT²-YR scale. This is how many kilowatt-hours per square foot per year daylighting will save for the building.

—> Record this in Line 25 of the worksheet—Daylighting Energy Consumption Savings

continued on Page 21



Nomograph 5

STEP 5, continued

Find lighting energy and cost savings due to daylighting.

■ THIRD, continued

- Continue down to intersect your Electricity Cost line (worksheet Line 13).
 - Move right and read your intersecting value on the Lighting Cost/Savings scale. This is the lighting cost savings per square foot per year from daylighting.
- > Record this in Line 26 of the worksheet—Daylighting Energy Cost Savings
- Multiply the above value (Line 26) by Building Area (Line 14). This is the annual lighting energy savings from daylighting.
- > Record this in Line 27 of the worksheet—Annual Daylighting Energy Savings.

STEP 6

Find the reduction in peak electrical demand and associated cost savings with daylighting.

■ FIRST

Estimate the electric load (W/ft²) of all non-lighting activities like mechanical heating and cooling, ventilation, office equipment use, etc.

- Mechanical engineer can provide this information.
 - Or, assume 3.5 W/ft².
- > Record Non-Lighting Electric Loads in Line 15 of the worksheet.

■ SECOND

Find the peak demand rate for local utility. Call the utility for current rate, or use one of these values:

San Diego Gas & Electric	\$19
Los Angeles Dept of Water & Power	9
Pacific Gas & Electric	13
Southern California Edison	17

—> Record Peak Demand Rate in Line 16 of the worksheet.

■ THIRD

Use Nomograph 6 to find lighting electrical demand and demand costs for a *non-daylighted* building.

- Enter at the middle left Lighting Load scale (*not* the top right start point shown in the key, but rather at the point in the key where the path forks in two directions), with your Installed Lighting Load value (worksheet Line 12).
- Move diagonally down to the right (parallel with the dashed lines), then move right to the vertical scale Building Electric Load.
- Move down this scale the number of watts per square foot you have in Non-Lighting Load (worksheet Line 15). In other words, end up at the value that equals your lighting plus non-lighting load.
- Move right to the diagonal line for your Total Building Area (worksheet Line 14). If building area exceeds 10,000 ft², then use a multiplier. For example, if you have a 700,000 ft² building, use the 7000 ft² line and multiply your final result by 100.

continued on Page 22

- Move up and read the value at your intersection with the KW Peak Demand scale. If you used a multiplier for your Building Area, multiply this value by that factor.
- > Record this in Line 28 of the worksheet—Non-Daylit Peak Demand.
- Now return to your entry point at the middle left with your Installed Lighting Load (worksheet Line 12).
- Move down vertically to the diagonal line for your Peak Demand Rate (worksheet Line 16).
- Move right to the first vertical scale, \$/ft²-month. This is the monthly demand charge for electric lighting.
- > Record this in Line 29 of the worksheet—Non-Daylit Monthly Demand Charge.
- Continue right to the second vertical scale, \$/ft²-year. This is the annual demand charge for electric lighting.
- > Record this in Line 30 of the worksheet—Non-Daylit Annual Demand Charge.

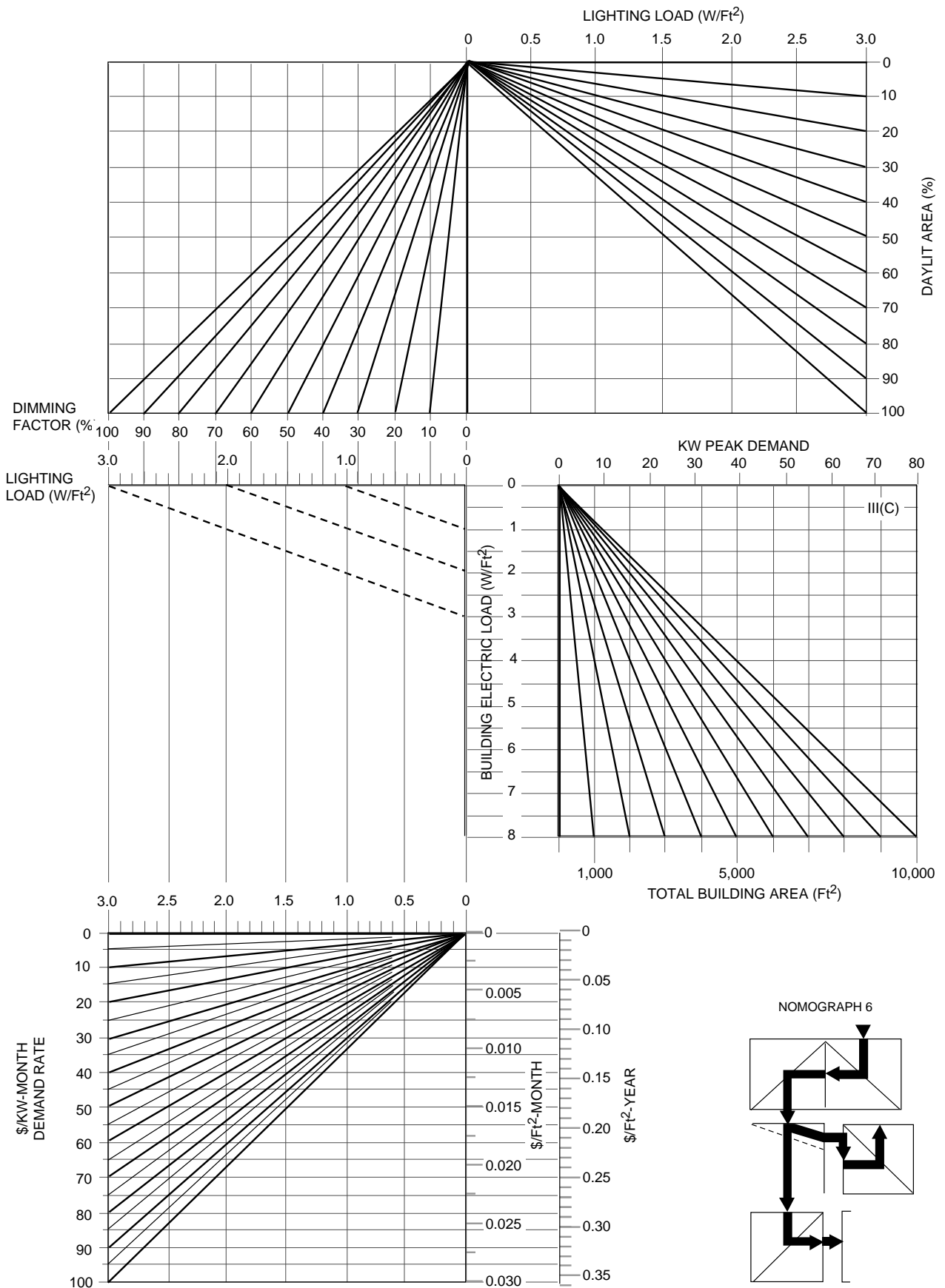
■ FOURTH

Use Nomograph 6 again, this time to find lighting energy and lighting costs for a *daylighted* building.

- Now start at the upper right as shown in the key, with your Installed Lighting Load value (worksheet Line 12).
- Move down to the diagonal line for your Daylit Area % (worksheet Line 20).
- Move left to the diagonal line for your Dimming Factor % (worksheet Line 19).
- Move down to the Lighting Load scale and mark your point of intersection (this will not be your actual lighting load, it's just a reference point).
- Move diagonally down to the right (parallel with the dashed lines), then horizontally to the vertical scale Building Electrical Load.
- Do *not* move down along this scale as before to add in other loads, but rather move directly right to the diagonal line for your Building Area. If building exceeds 10,000 ft², use a multiplier as before.
- Move up and read the value at your intersection with the KW Peak Demand scale. This is the peak demand *reduction* due to daylighting. If you used a multiplier for your Building Area, multiply this value by that factor.
- > Record this in Line 31 of the worksheet—Daylit Peak Demand Savings.
- Return to the point you marked on the Lighting Load scale.
- Move down to the diagonal line for your Peak Demand Rate (worksheet Line 16).
- Move right to the first vertical scale, \$/ft²-month. This is the monthly demand savings due to daylighting.
- > Record this in Line 32 of the worksheet—Daylit Monthly Demand Savings.
- Continue right to the second vertical scale, \$/ft²-year. This is the annual demand savings due to daylighting.
- > Record this in Line 33 of the worksheet—Daylit Annual Demand Savings.
- Now calculate the total savings per year due to daylighting. Simply add Daylighting Energy Cost Savings (worksheet Line 26) and Daylit Peak Demand Savings (worksheet Line 33) together.
- > Record this in Line 34 of the worksheet—Total Annual Savings.

Note: You may wish to perform this procedure separately for different summer and winter demand charges, if your local utility has seasonal rate structures.

Note: The annual savings yielded here (the final value read from the nomograph) is simply 12 times the monthly value. If demand charges are not in place all 12 months of the year, calculate annual savings manually. For example, if demand charges only apply for 6 months, then multiply your monthly value by six for the annual value, rather than reading from the scale in the nomograph.



Nomograph 6

STEP 7

Assess attractiveness of investment in daylighting strategies.

The full economic impact of an energy efficiency design decision is difficult to anticipate due to so many unknowns in how a proposed building will actually be constructed and operated. The nomographs you have used up to this point were developed with many simplifying assumptions. This means that the performance expectations you have determined through the nomographs are only a rough estimate of the energy performance your proposed building may actual exhibit. Because economic analysis must be based on predicted energy performance, any investment information determined in this final step will be equally rough. Further complicating this is the fact that investment decisions are complex due to unknowns on the financial horizon, such as future inflation rates, future alternative earnings for this investor, and rises in the cost of energy. The designer is cautioned to make use of this final nomograph with care.

■ Option 1: Simple Payback Calculation

This rough, quick analysis procedure is frequently used when the investor (the building owner) is primarily interested in a short payback period. Payback period is the time it takes for a more expensive technology to pay for itself through the operations savings it yields over its less costly equivalent. You can calculate justifiable investment based on a desired payback length taking the simple steps below. The nomograph is not used in this option.

- Begin with Total Annual Savings due to daylighting (worksheet Line 34).
- If possible, assign an economic value (in \$/ft²-year) for the non-energy benefits of daylighting. Some examples: increased rental value of daylit spaces, increased occupant productivity, increased resale value of the building. Add this into Total Annual Savings.
- Determine the maximum acceptable payback period, in years.

—> Record Payback Period in Line 37 of the worksheet.

- Multiply Total Annual Savings (\$/ft²-year) by Payback Period (years). This equals the maximum justifiable investment for daylighting, in \$/ft². This will typically only be spent in the daylighted zones, not the whole building.

■ Option 2: Maximum Justifiable Investment Given a Desired Payback Period

Use Nomograph 7 to determine the maximum investment, or first cost, that is justifiable based upon projected savings and a given payback period. The "Justifiable Investment" is not the sum that is generally spent throughout the building, but is more likely the sum spent on lighting controls in the perimeter zone. The additional costs for improved glazing, glare control, and direct sun control for glazed areas can be included, but remember that this analysis does not account for reductions in cooling energy. This method includes the discounted value of future savings and the effects of escalating energy costs.

- Begin at the Discount Rate scale, with your value from worksheet Line 38.
- Move up to the curve for your Energy Escalation Rate (worksheet Line 39).
- Move right to the curve corresponding to desired Payback Period (worksheet Line 37).
- Move down to the region of diagonal lines for First Year Savings. Choose the line that corresponds to your value for Total Annual Savings (worksheet Line 34).
- Move left and record the value at your intersection with the Justifiable Investment scale. This is the maximum added cost for daylighting design to yield a sensible investment. Note that this cost will typically only be spent in the daylighted zones, not the whole building.

—> Record Justifiable Investment in Line 35 of the worksheet.

■ Option 3: Minimum Savings Required to Justify a Given Investment

This is the inverse of Option 2. For a given desired payback period and given the added first cost for daylighting design, find the first year savings necessary to justify that investment using Nomograph 7.

- Begin at the Discount Rate scale, with your value from worksheet Line 38.
- Move up to the curve for your Energy Escalation Rate (worksheet Line 39).
- Move right to the curve corresponding to desired Payback Period (worksheet Line 37).
- Move down until you intersect the *horizontal* line on the left-hand scale marked Justifiable Investment that corresponds to the given investment. Mark this point.
- The point should be within the range of diagonal lines corresponding to First Year Savings. Interpolate your required First Year Savings. Your daylighting design must yield this in order to justify the given investment.
- If that point is not within the range First Year Savings diagonal lines, then try a lower discount rate or a longer payback period.

—> Record First Year Savings in Line 36 of the worksheet.

■ Option 4: Required Payback Period Given First Year Savings and Available Investment

Given the annual savings and funds available for investment, find the number of years required to pay back that investment using Nomograph 7.

- Begin at the Discount Rate scale, with your value from worksheet Line 38.
- Move up to the curve for your Energy Escalation Rate (worksheet Line 39).
- Move to the right and intersect the vertical scale (running from 0.75 to 1.40). Mark that value for use in a moment.
- Go to the Justifiable Investment scale, find the value of your available investment (worksheet Line 35) and move right to intersect the diagonal line for your First Year Savings (worksheet Line 36, or use value in Line 34).
- Move up until you intersect the horizontal line corresponding to the value you marked before. That point of intersection should fall within the range of curves for payback period Number of Years. Interpolate your required payback between the two curves nearest your point. If your point is not within the region of curves, then your payback is greater than 100 years.

—> Record Required Payback in Line 37 of the worksheet.

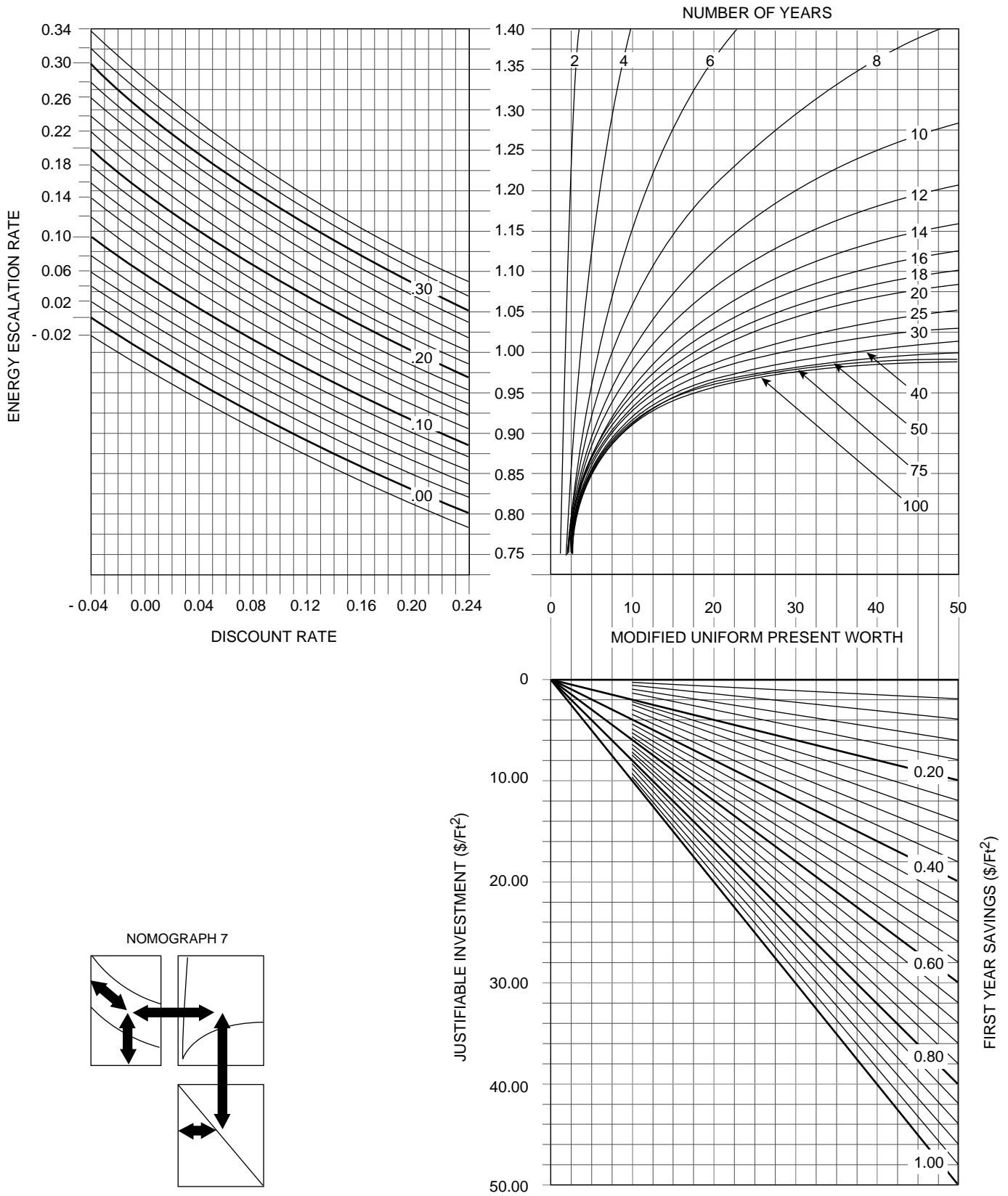
■ Option 5: Rate of Return on Investment

Given an investment value, annual savings, and payback period, find the rate of return on initial investment using Nomograph 7.

- Start at the Justifiable Investment scale, find the value of your intended investment (worksheet Line 35) and move right to intersect the diagonal line for your First Year Savings (worksheet Line 36, or use value in Line 34).
- Move up to the curve for your given payback period (worksheet Line 37).
- Move left to the curve for your energy escalation rate (worksheet Line 39).
- Move down and read the value at your intersection with the Discount Rate scale. This is the Rate of Return on Investment.

—> Record this value in Line 38 of the worksheet.

This concludes this Nomograph Cost/Benefit Tool for Daylighting. For detailed information, consult the original research: S.E. Selkowitz and M. Gabel. 1984. "LBL Daylighting Nomographs," LBL-13534, Lawrence Berkeley Laboratory, Berkeley CA, 94704. (510) 486-6845.



Nomograph 7