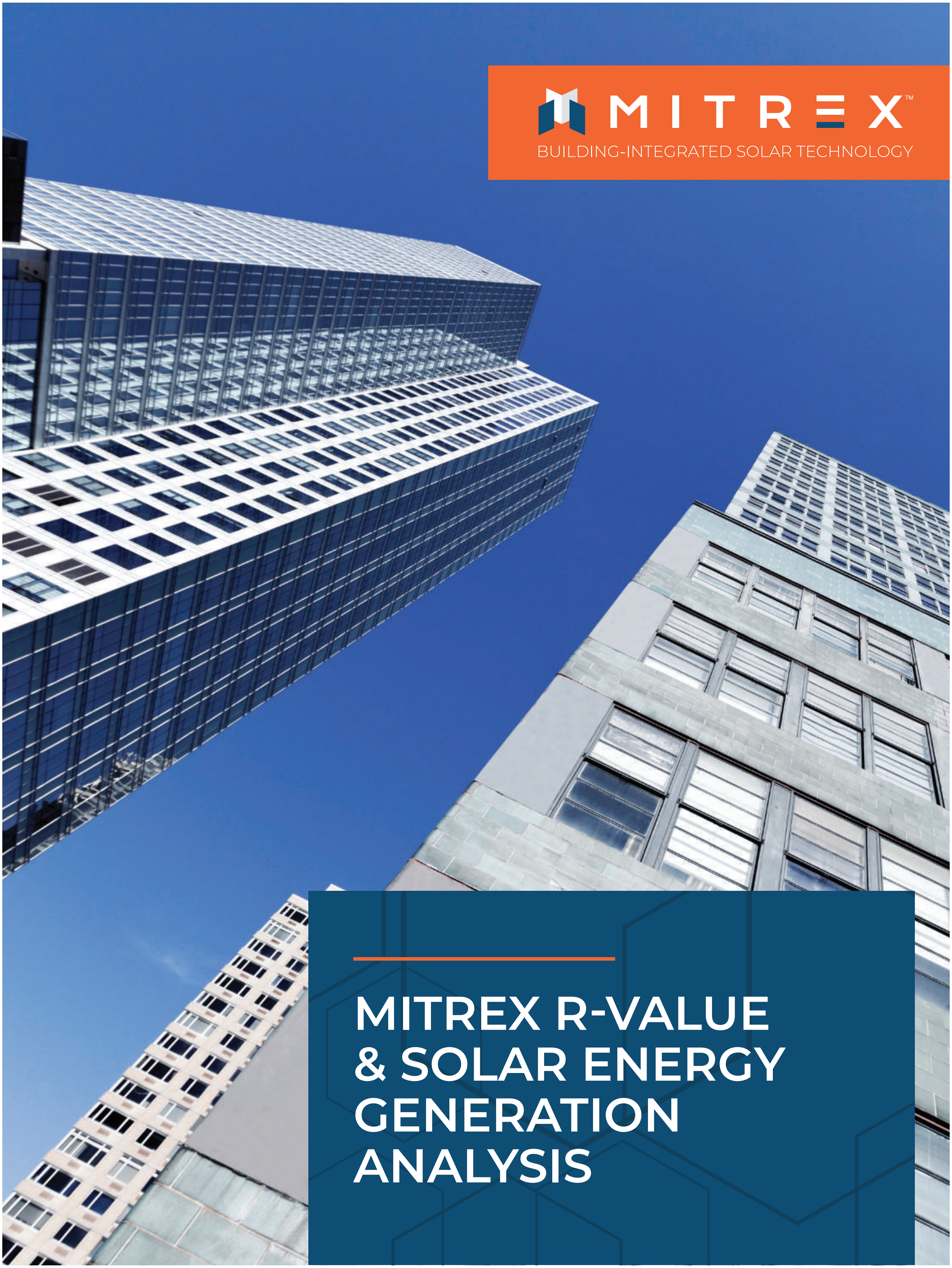


MITREX

BUILDING-INTEGRATED SOLAR TECHNOLOGY

MITREX R-VALUE & SOLAR ENERGY GENERATION ANALYSIS

1. INTRODUCTION

This comprehensive table illustrates the energy-saving benefits of various R-Values, representing insulation effectiveness. As R-Values increase, energy losses decrease significantly. Additionally, the table presents power percentages for a 400W solar panel in different orientations—South, West, East, and North. These percentages highlight the net annual power production in relation to the net energy loss. It is noteworthy that higher R-Values not only minimize energy losses but also increase the relative effectiveness of solar power generation. For instance, in Toronto at R-1, the solar panel produces 27% of the net energy loss in the South, 22% in the West, 22% in the East, and 11% in the North. However, at R-50, the relative power generation soars to 1366% in the South, 1116% in the West, 1107% in the East, and 545% in the North. Make informed decisions to maximize energy efficiency and harness the full potential of solar power with our insightful analysis.

2. R-VALUE & SOLAR ENERGY GENERATION IN DIFFERENT LOCATIONS

While the R-value focuses on energy loss through insulation, BIPV systems primarily concentrate on energy generation through solar radiation. The two concepts are not directly convertible, but a comparison can be made to understand their combined impact on a building's energy performance.

TORONTO	ANNUALLY PER SQFT			BIPV COMPENSATION FACTOR (EQUIVALENT) 400W			
R-Value	Winter Heating Loss (kWh)	Summer Cooling Loss (kWh)	Net Energy Loss (kWh)	South	West	East	North
1	46.50	5.50	52.04	27%	22%	22%	11%
10	4.65	0.55	5.20	273%	223%	221%	109%
20	2.33	0.27	2.60	546%	446%	443%	218%
30	1.55	0.18	1.73	819%	669%	664%	327%
40	1.16	0.14	1.30	1093%	893%	885%	436%
50	0.93	0.11	1.04	1366%	1116%	1107%	545%

LOS ANGELES	ANNUALLY PER SQFT			BIPV COMPENSATION FACTOR (EQUIVALENT) 400W			
R-Value	Winter Heating Loss (kWh)	Summer Cooling Loss (kWh)	Net Energy Loss (kWh)	South	West	East	North
1	7.23	9.85	17.08	261%	225%	234%	99%
10	0.72	0.98	1.71	2611%	2255%	2339%	993%
20	0.36	0.49	0.85	5222%	4509%	4678%	1985%
30	0.24	0.33	0.87	7833%	6764%	7017%	2978%
40	0.18	0.25	0.43	10444%	9019%	9356%	3971%
50	0.14	0.20	0.34	13055%	11274%	11695%	4964%

HOUSTON	ANNUALLY PER SQFT			BIPV COMPENSATION FACTOR (EQUIVALENT) 400W			
R-Value	Winter Heating Loss (kWh)	Summer Cooling Loss (kWh)	Net Energy Loss (kWh)	South	West	East	North
1	3.09	23.65	26.74	137%	1255%	127%	63%
10	0.31	2.36	2.67	1365%	1245%	1273%	634%
20	0.15	1.18	1.34	2730%	2491%	2546%	1268%
30	0.10	0.79	0.89	4096%	3736%	3820%	1902%
40	0.08	0.59	0.67	5461%	4982%	5093%	2536%
50	0.06	0.47	0.53	6826%	6227%	6366%	3170%

NEW YORK	ANNUALLY PER SQFT			BIPV COMPENSATION FACTOR (EQUIVALENT) 400W			
R-Value	Winter Heating Loss (kWh)	Summer Cooling Loss (kWh)	Net Energy Loss (kWh)	South	West	East	North
1	31.03	9.18	40.21	102%	79%	82%	38%
10	3.10	0.92	4.02	1023%	791%	817%	380%
20	1.55	0.46	2.01	2047%	1583%	1633%	760%
30	1.03	0.31	1.34	3070%	2374%	2450%	1140%
40	0.78	0.23	1.01	4094%	3165%	3267%	1520%
50	0.62	0.18	0.80	5117%	3956%	4083%	1900%

MIAMI	ANNUALLY PER SQFT			BIPV COMPENSATION FACTOR (EQUIVALENT) 400W			
R-Value	Winter Heating Loss (kWh)	Summer Cooling Loss (kWh)	Net Energy Loss (kWh)	South	West	East	North
1	0.38	37.15	37.53	98%	94%	95%	47%
10	0.04	3.71	3.75	983%	943%	951%	468%
20	0.02	1.86	1.88	1966%	1886%	1901%	936%
30	0.01	1.24	1.25	2948%	2830%	2852%	1404%
40	0.01	0.93	0.94	3931%	3773%	3803%	1872%
50	0.01	0.74	0.75	4914%	4716%	4753%	2339%

Our calculation process involves utilizing heating degree days (HDD) and cooling degree days (CDD) to determine the values in question. HDD and CDD are derived by calculating the average daily outdoor temperature (in °C/°F) and measuring the difference from a reference temperature of 18°C/65°F. By summing these values over the course of a year, we obtain an understanding of the heating and cooling requirements. In the case of Toronto in 2022, there were 3676°C (6616.8°F) HDD and 434°C (781°F) CDD. You can find this information in the provided links for Canada and the USA.

Canada: https://toronto.weatherstats.ca/charts/hdd-yearly.html
USA: https://www.weather.gov/wrh/climate

Using these HDD and CDD values, we can proceed to calculate the winter heat loss and summer cooling loss, with the net power energy loss being the sum of both. The formulas we employ are as follows:

$$Winter\ Heat\ Loss\ (kWh) = \frac{1}{R * 0.176} * HDD(°C) * \frac{24}{1000}$$

$$Summer\ Cooling\ Loss\ (kWh) = \frac{1}{R * 0.176} * CDD(°C) * \frac{24}{1000}$$

To determine the annual energy production of a solar panel per square foot, we take into account the number of sunlight hours a city receives throughout the year. Using Toronto as an example, the respective annual energy production values (in kWh) per square foot for different orientations are as follows:

ORIENTATION	ANNUAL ENERGY PRODUCTION PER SQFT
South	14.11 kWh
West	11.61 kWh
East	11.52 kWh
North	5.67 kWh

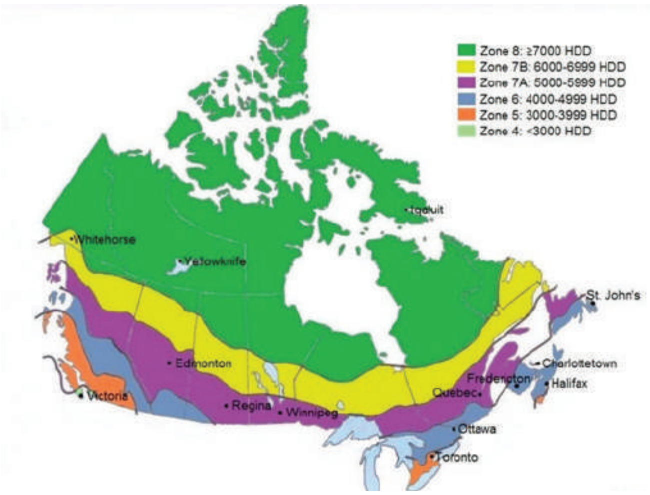
Lastly, we calculate the BIPV (Building-Integrated Photovoltaics) compensation factor. This factor is obtained by dividing the annual energy production of the solar panel by the net power energy loss, expressed as a percentage. It illustrates the solar panel's power generation relative to the insulation's performance.

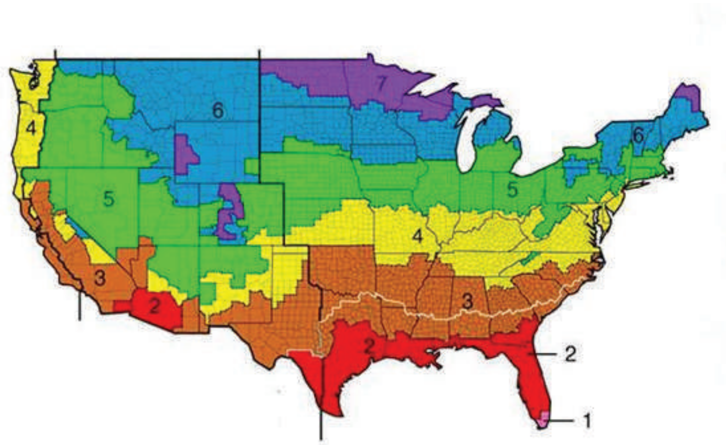
3. CLIMATE VARIATION AND INSULATION BY LOCATION

The climate varies in each city, and these variations are categorized into different zones based on the number of heating degree days. Each zone has specific insulation requirements. To determine these requirements, you can refer to the following sources:

1. **For Canadian cities, such as Toronto:** https://www.homedepot.ca/en/home/ideas-how-to/home-repair-and-maintenance/how-to-choose-insulation.html

2. **For cities in the United States:** https://codes.iccsafe.org/content/FEC2017/chapter-4-re-residential-energy-efficiency





CITY	CLIMATE ZONE	INSULATION REQUIREMENTS
Toronto	5	22
Los Angeles	3	20
Houston	2	13
Miami	2	13
New York	4	20

When it comes to windows, a typical double-glazed window has an R-Value of 3.7, while a triple-glazed window has an R-Value of 4.3. With these values, you can calculate the expected heat loss for different window-to-wall ratios using the formula:

$$WW_x = NetEnergyLoss_{Wall} * WW_x + NetEnergyLoss_{Window} * (1 - WW_x)$$

Where WW_x would be the window wall ratio ($WW_{0.2} = 0.2$)

Here is the data for annual heat loss (kWh/sqft) based on different window-to-wall ratios for each city and window glazing type:

CITY		WINDOW-WALL RATIO ANNUAL HEAT LOSS (kWh / SQFT)						
	Window Glazing	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
Toronto	Double Pane	4.7	5.9	7.0	8.2	9.4	10.6	11.7
	Triple Pane	4.3	5.3	6.3	7.2	8.2	9.2	10.2
Los Angeles	Double Pane	1.6	2.0	2.4	2.7	3.1	3.5	3.9
	Triple Pane	1.5	1.8	2.1	2.4	2.7	3.0	3.3
Houston	Double Pane	3.1	3.6	4.1	4.6	5.2	5.7	6.2
	Triple Pane	2.9	3.3	3.7	4.1	4.6	5.0	5.4
Miami	Double Pane	4.3	5.1	5.8	6.5	7.2	8.0	8.7
	Triple Pane	4.1	4.6	5.2	5.8	6.4	7.0	7.6
New York	Double Pane	3.8	4.7	5.6	6.4	7.3	8.2	9.1
	Triple Pane	3.5	4.2	4.9	5.7	6.4	7.1	7.9

Additionally, you can calculate the BIPV (Building Integrated Photovoltaics) compensation factor for different cities and window glazing types. The compensation factor considers a smaller amount of BIPV as the window size increases. Please note that these calculations do not account for solar heat gain through a window.

CITY		BIPV COMPENSATION FACTOR						
	Window Glazing	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Toronto	Double Pane	241.7%	169.4%	121.1%	86.5%	60.6%	40.4%	24.2%
	Triple Pane	263.7%	188.2%	136.2%	98.3%	69.3%	46.4%	28.0%
Los Angeles	Double Pane	2220.7%	1574.5%	1134.3%	815.3%	573.3%	383.6%	230.8%
	Triple Pane	2414.5%	1744.5%	1273.4%	924.1%	654.7%	440.4%	266.4%
Houston	Double Pane	944.9%	708.3%	531.0%	393.2%	283.0%	193.0%	117.9%
	Triple Pane	10.0.8%	773.1%	588.6%	441.1%	320.7%	220.4%	135.6%
Miami	Double Pane	680.2%	509.9%	382.3%	283.1%	203.8%	138.9%	84.9%
	Triple Pane	727.7%	556.6%	423.7%	317.6%	230.8%	158.6%	97.6%
New York	Double Pane	870.5%	617.2%	444.6%	319.6%	224.7%	150.4%	90.5%
	Triple Pane	946.4%	683.8%	499.1%	362.2%	256.6%	172.7%	104.4%

4. IMPLICATIONS FOR SUSTAINABLE DESIGN

By comparing the energy loss of a building based on its R-value with the potential energy generation of BIPV, we can gain valuable insights into the overall energy dynamics. In some cases, the energy loss of a building can be significantly offset by the energy generation capabilities of BIPV systems. Research suggests that BIPV can potentially offset the building's energy loss by a factor of 130X, highlighting the significant impact these integrated solar solutions can have on a structure's energy efficiency.

The ability of BIPV systems to counterbalance energy loss in a building is of great importance in sustainable design. By integrating renewable energy generation directly into the building envelope, we can effectively reduce the reliance on external energy sources and minimize the overall environmental impact. Additionally, the integration of BIPV systems can contribute to the reduction of greenhouse gas emissions and foster a more sustainable and resilient built environment.

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