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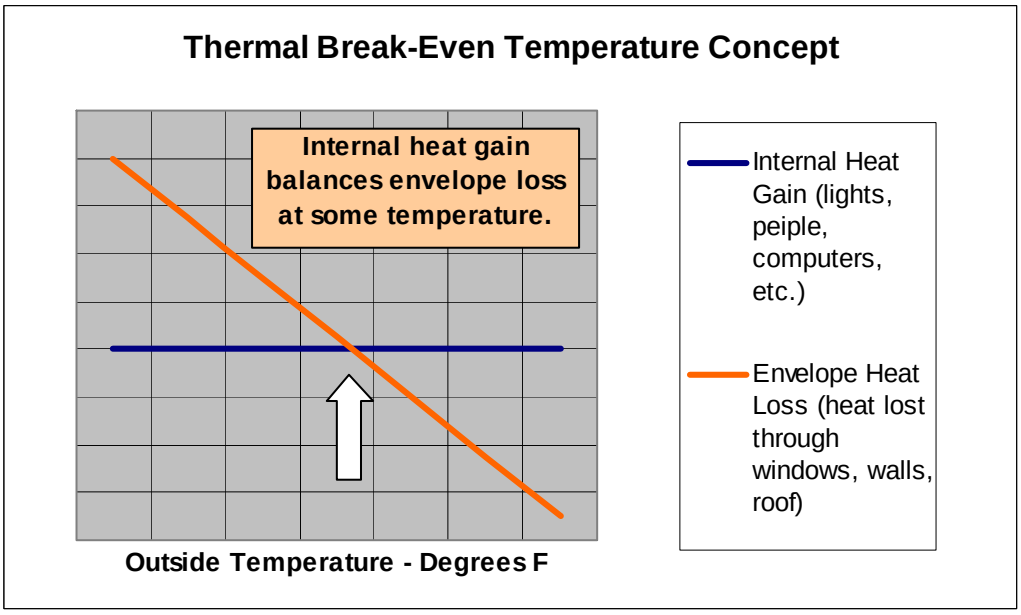
White Paper #11

Free Cooling – Outside Air Economizer

It's like opening a window when it's hot inside and cool outside. How much does it save? The easy answer is "it depends." To really find out, read further. You'll see there are a lot of factors.

Like all heat recovery concepts, a pre-requisite for success is to have the free heat (or free cooling) available at the same location and time as there is a need for it. The free heat in Atlanta has no practical use in Alaska because they are too far apart. Likewise, free cooling from outdoors doesn't provide any value unless it is warm indoors at that time.

Buildings are like boxes. They have thermal losses and gains through the shell (envelope), and they also have appliances and activities inside that generate heat. There will be a point where the envelope loss just matches the internal heat gains and neither heating nor cooling is required; above this break-even temperature cooling will be required.



The thermal break-even point is unique for each building. The magnitude of the envelope in relation to the internal gains creates a cooling load 'signature' for the building. This signature is an important factor in determining how much benefit can be expected from an air-side economizer. For example, the heating and cooling load for a house comes mostly from the envelope. So, when it's cold outside it's usually cold inside a house and this is why our homes are not good candidates for an air side economizer. In many commercial buildings, the heat produced by what goes on inside will offset heat losses in cool or cold weather, resulting in a need for some cooling even while cold outside. When this is the case and air-economizer is a benefit.

The greater the internal loads are, in proportion to the envelope losses, the greater the benefit of an air-economizer, because the thermal break even point is lower. With a low break-even temperature, there are more hours when the building needs cooling *and it happens to also be cool outside*.

To sum it up: ***the lower the break even point, and the greater the number of hours this occurs, the greater the benefit.***

What is your building's break even temperature? An engineer can calculate this, or you can estimate it from your building's heating and cooling system behavior, with a little patience. As the weather moves from summer to fall, make notes of whether the HVAC systems are providing heating or cooling, especially equipment serving the building perimeter. The HVAC systems will be cooling in summer, obviously. As temperatures drop during fall, eventually the systems will switch to heating. As long as the interior energy use remains steady, you can identify the break-even point for your building by noting the approximate outside temperature when the heating just begins. With that number, you can use the charts at the end of this paper to find the approximate beneficial hours and fraction of the annual cooling load provided by the air economizer – which represents the energy you save. You will note there is a big difference in savings depending on how many hours the building systems are operated.

EXTENDED ECONOMIZER OPERATION

The 55 degree cutoff point is often used to simplify system design and operation, and to eliminate worries about humidity issues in the space.

At or below 55 degrees, ALL of the air circulating can be from outdoors with NO mechanical cooling at all, so it is very simple to have an outdoor air thermostat turn off the compressors and enable the economizer damper controls at this temperature. At 55 degrees outside air (OA), the moisture content of that air does not matter. Above 55 degrees OA, the air ***may or may not be suitable*** for use in free cooling – depending upon its moisture content. The air in Colorado is usually, although not always, suitable for use at temperatures up to 65 degrees.

Using the conventional 55 degree cutoff strategy, the compressors turn off and the free cooling dampers take over whenever the OA temperature is below 55 deg. It's one or the other. .

For extended economizer operation, the ***compressors run in conjunction with the free cooling dampers.*** By expelling the building "return" air and replacing it with outside air, this acts to lower the heat content of the air stream entering the mechanical cooling unit coil. A maximum of 65 degrees and 47 degrees dew point is suggested for this extended operation. If dew point cannot be conveniently measured or calculated, the same thing can be done with relative humidity and a sliding scale, as follows:

Suggested Maximum Relative Humidity for use in Air Economizer "Free Cooling"

OA Temperature Degrees F	OA Dewpoint Degrees F	OA Relative Humidity
65 deg	47 deg	48%
64 deg	47 deg	50%
63 deg	47 deg	53%
62 deg	47 deg	55%
61 deg	47 deg	57%
60 deg	47 deg	59%
59 deg	47 deg	60%
58 deg	47 deg	62%
57 deg	47 deg	66%
56 deg	47 deg	70%
55 deg	any	any

By raising the cut-off point 10 degrees, the hours of use and savings for the air-economizer are extended, and can be attractive. To capture these savings, some additional investment in controls and system attention are required. To decide if the Extended Economizer approach is worth it for you, weigh the benefits against the added cost and complication and then decide.

A Few 'Watch-Outs' for Air-Economizers

- Economizer dampers moving around can affect building pressure. If not properly specified or controlled, you may experience problems like the building front doors standing open, or feeling a "vacuum" on the doors, making them hard to open. In extreme cases, you may experience ceiling tiles lifting. If any of this is happening, it can usually be improved with control adjustments, provided there is either a return fan or a power exhaust. If the building routinely becomes "negative" (the vacuum effect) this is a particular concern in winter, since it is then possible for pipes to freeze if located near a perimeter – depending on where the cold air finds a way inside.

- For buildings with low break even points, using very cold air for cooling requires that it be "mixed" with the return air, and blended to make a reasonable air delivery temperature. The colder the air gets, the more it tends to settle to the bottom by its density. This is called "stratification" and can cause freezing damage or nuisance tripping of freeze controls. If your system uses an air economizer in very cold weather, some method of mechanically mixing the air streams will be required to avoid these troubles.

- Outside air used for free cooling will have varying amounts of moisture. When used to cool a building, the air becomes warmed and the relative humidity drops. Just as the outside air relative humidity varies throughout the year, so will the relative humidity inside the space. This is natural and should be accepted as part of the "free cooling" benefit. If close control of humidity is important, or humidity must be kept above certain levels, the air economizer may not be for you. Adding a humidifier to the system to control moisture is not a good solution for this, since it adds significant energy costs to the system.

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APPROXIMATE ECONOMIZER COOLING LOAD PERCENT SAVINGS - COLORADO SPRINGS (55 Deg Cutoff)

		24X7			6AM-6PM		
ECONOMIZER CUT-OFF	BREAK EVEN TEMP	ECONOMIZER HOURS	TOTAL CLG HOURS	PCT ANNUAL CLG LOAD	ECONOMIZER HOURS	TOTAL CLG HOURS	PCT ANNUAL CLG LOAD
55	63	0	2344	0%	0	1203	0%
55	59	0	2834	0%	0	1378	0%
55	55	0	3625	0%	0	1628	0%
55	51	1045	4213	2%	337	1835	2%
55	47	1610	4778	6%	549	2047	5%
55	43	2197	5365	10%	760	2258	8%
55	39	2746	5914	14%	932	2430	11%
55	35	3453	6621	18%	1159	2657	15%
55	31	3993	7161	22%	1317	2815	18%
55	27	4446	7614	25%	1465	2963	21%
55	23	4790	7958	28%	1574	3072	23%
55	19	5104	8272	30%	1661	3159	26%
55	15	5278	8446	32%	1713	3211	27%
55	11	5389	8557	34%	1766	3264	29%
55	7	5466	8634	35%	1799	3297	30%
55	3	5517	8685	37%	1813	3311	32%
55	-1	5576	8744	38%	1826	3324	33%

APPROXIMATE ECONOMIZER COOLING LOAD PERCENT SAVINGS - COLORADO SPRINGS (65 Deg Cutoff)

		24X7			6AM-6PM		
ECONOMIZER CUT-OFF	BREAK EVEN TEMP	ECONOMIZER HOURS	TOTAL CLG HOURS	PCT ANNUAL CLG LOAD	ECONOMIZER HOURS	TOTAL CLG HOURS	PCT ANNUAL CLG LOAD
65	63	581	2344	1%	224	1203	0.8%
65	59	1071	2834	4%	399	1378	3%
65	55	1862	3625	8%	649	1628	7%
65	51	2450	4213	19%	856	1835	16%
65	47	3015	4778	25%	1068	2047	20%
65	43	3602	5365	30%	1279	2258	25%
65	39	4151	5914	34%	1451	2430	29%
65	35	4858	6621	38%	1678	2657	33%
65	31	5398	7161	41%	1836	2815	36%
65	27	5851	7614	44%	1984	2963	39%
65	23	6195	7958	47%	2093	3072	41%
65	19	6509	8272	49%	2180	3159	43%
65	15	6683	8446	51%	2232	3211	45%
65	11	6794	8557	52%	2285	3264	46%
65	7	6871	8634	54%	2318	3297	47%
65	3	6922	8685	55%	2332	3311	49%
65	-1	6981	8744	56%	2345	3324	50%

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Building Type	Internal Gains or Envelope Dominates?	Approximate Break Even Temp (estimates)	Air-Economizer Viable?	Approx. Annual Savings % of annual cooling costs			
				24x7 55 deg cutoff	6a-6p 55 deg cutoff	24x7 65 deg cutoff	6a-6p 65 deg cutoff
General - Residential	Envelope	65	No	0	0	1%	0.5%
General – Buildings with a low percentage of perimeter surface area (e.g. cube shaped)	Internal Gains	Varies	Yes	Varies	Varies	Varies	Varies
General – Large building core areas	Internal Gains	Varies	Yes	Varies	Varies	Varies	Varies
General – Buildings with a large amount of perimeter envelope area compared to interior area.	Envelope	65	No	0	0	1%	0.5%
Apartments, Condominiums, Hotel Guest Rooms	Envelope	65	No	0	0	1%	0.5%
Assembly area with high people density (church, theatre, ballroom)	Internal Gains	20-40	Yes	29-13%	25-10%	48-33	42-27
Church building, other than busy times	Envelope	65	No	0	0	1%	0.5%
Office building interior areas	Internal Gains	40-50	Yes	13-3%	10-2.5%	33-20%	27-17%
Office building perimeter areas, near the glass, standard construction	Varies	50-60	Marginal	3-0%	2.5-0%	20-3%	17-2.5%
Office building perimeter areas, near the glass, high performance glazing and well insulated.	Internal Gains	40-50	Yes	13-3%	10-2.5%	33-20%	27-17%
Restaurant – Kitchen	Internal Gains	30-40	Yes	23-13%	19-10%	42-33%	38-27%
Restaurant – Dining Area with windows	Envelope	65	No	0	0	1%	0.5%
Warehouse that is heated and cooled, but used just for storage	Envelope	65	No	0	0	1%	0.5%
School class rooms, standard room filled with students	Internal Gains	40-50	Yes	13-3%	10-2.5%	33-20%	27-17%
Light manufacturing, low activity, minor interior equipment loads, sparse people loading.	Envelope	55-65	Marginal	0	0	8-1%	7-0.5%
Hot Process Manufacturing, Ovens, Baking, Cooking, etc.	Internal Gains	10-30	Yes	34-23%	29-19%	52-42%	46-38%
Computer data center, 40W/SF	Internal Gains	0	No. Most Computer Equipment is Humidity-Sensitive	N/A	N/A	N/A	N/A