### Destratification Fan

###### Description

This measure applies to buildings with high bay ceiling construction without fans currently installed for the purpose of destratifying air. There is also a separate measure for destratification fans as applied to agricultural settings (“High Volume Low Speed Fans”). All other destratification fan applications require custom analysis.

Air stratification leads to higher temperatures at the ceiling and lower temperatures at the ground. During the heating season, destratification fans improve air temperature distribution in a space by circulating warmer air from the ceiling back down to the floor level, thereby enhancing comfort and saving energy. Energy savings are realized by a reduction of heat loss through the roof-deck and walls as a result of a smaller temperature differential between indoor temperature and outdoor air.

Note that further, but limited, empirical evidence suggests that improved air mixing due to destratification would also result in shorter heating system runtimes due to warmer air reaching the thermostat level sooner, and possibly even allow a facility to lower the thermostat set point while maintaining a similar level of occupant comfort. This is supported by measured data in which an increase in temperatures was observed at the thermostat (5 foot level) level when air is destratified, resulting in an approximate temperature increase at the 5 foot level in the range of 1 - 3oF[[1]](#footnote-1). This measure does not currently attempt to quantify the potential impacts of air mixing from destratification; however, it should be noted that additional therms savings may be possible.

This measure was developed to be applicable to the following program types: NC, RF. If applied to other program types, the measure savings should be verified.

*Limitations*

* For use in conditioned, high bay structures. Recommended minimum ceiling height of 20 ft.
* This measure should only be applied to spaces in which the ceiling is subject to heat loss to outdoor air (i.e., single story or top floor spaces) and where there is sufficient space to allow for appropriate spacing of the fans. Other applications require custom analysis.

Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Please see calculation of effective area, Aeff, in the therms savings algorithm as a check if this criteria is met. Otherwise, custom calculation is necessary.

Measure does not currently support facilities with night setbacks on heating equipment. Custom analysis is needed in this case.

* Certain heating systems may not be a good fit for destratification fans, such as locations with: high velocity vertical throw unit heaters, radiant heaters, and centralized forced air systems. In these cases, measured evidence of stratification should be confirmed and custom analysis may be necessary.

###### Definition of Efficient Equipment

High Volume, Low Speed (HVLS) fans with a minimum diameter of 14 ft with Variable Speed Drive (VSD) installed[[2]](#footnote-2).

Note that bell-shaped fans are currently excluded from this measure due to limited validation of the technology available. Further verification of effectiveness compared to HVLS is needed. A manufacturer of bell shaped fans indicates that four bell-shaped fans provide an equivalent effective area as a typical HVLS fan. However, there is a need for further review of bell shaped fan field test data supporting manufacturer claims regarding comparable effectiveness to HVLS technologies.

###### Definition of Baseline Equipment

No destratification fans or other means to effectively mix indoor air.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[[3]](#footnote-3)

###### Deemed Measure Cost

Measure cost = [incremental cost of HVLS fans] + [installation costs (including materials and labor)]

The incremental capital cost for HVLS fans are as follows[[4]](#footnote-4):

|  |  |
| --- | --- |
| Fan Diameter (ft) | Incremental Cost |
| 14 | $6,600 |
| 16 | $6,650 |
| 18 | $6,700 |
| 20 | $6,750 |
| 22 | $6,800 |
| 24 | $6,850 |

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

###### Loadshape

Loadshape C04: Commercial Electric Heating.

###### Coincidence Factor

N/A due to no savings attributable to cooling during the summer peak period.

**Algorithm**

###### Calculation of Savings

The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

###### Electric Energy Savings

The algorithm for this measure was developed for natural gas heating applications, however, for electric heating applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:

| **System Type** | **Age of Equipment** | **HSPF Estimate** | **η (Effective COP Estimate) (HSPF/3.413)\*0.85** |
| --- | --- | --- | --- |
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| 2006 - 2014 | 7.7 | 1.92 |
| 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1 |

Regardless of how the building is heated, the energy consumption of the fans must be accounted for. If the building is electrically heated, fan energy shall be subtracted from the savings as calculated above. If the building is heated with natural gas, this shall represent an electric penalty, i.e., an increase in consumption. This is calculated as follows:

∆kWh = - (Wfan \* Nfan) \* teff

Wfan = fan input power (kW)

Nfan = number of fans

teff = effective annual operation time, based on balance point temperature (hr)

= see table below in Natural Gas Savings section for further detail

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Energy Savings

∆Therms = [(∆Qr + ∆Qw) \* teff] / (100,000 \* η)

Where:

Qr = the heat loss reduction through the roof due to the destratification fan (Btu/hr)

= See calculation section below

Qw = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)

= See calculation section below

teff = effective annual operation time, based on balance point temperature (hr)

= use table below to select an appropriate value[[5]](#footnote-5):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **teff** | | | | |
| **Climate Zone -**  **Weather Station/City** | **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 1 -Rockford AP / Rockford | 3810 | 4226 | 4880 | 5571 | 6436 |
| 2 - Chicago O'Hare AP / Chicago | 3593 | 3986 | 4603 | 5254 | 6070 |
| 3 - Springfield #2 / Springfield | 3038 | 3370 | 3891 | 4442 | 5131 |
| 4 - Belleville SIU RSCH / Belleville | 2243 | 2488 | 2873 | 3280 | 3789 |
| 5 - Carbondale Southern IL AP / Marion | 2271 | 2519 | 2909 | 3320 | 3836 |

100,000 = conversion factor (1 therm = 100,000 Btu)

η = thermal efficiency of heating equipment

= Actual. If unknown assume 0.8.

For Example:

For a warehouse facility located in Rockford, IL, installing destratification fans could reduce heat loss through the roof of 95,000 Btu/hr and a reduced heat loss through the wall of 51,2282 Btu/hr. Assuming a balance point of 55oF the therms savings for the facility would be estimated as:

∆Therms = [(∆Qr + ∆Qw) \* teff] / (100,000 \* η)

= [(95,000 Btu/hr + 51,282 Btu/hr) \* 4880 hr] / [(100,000 Btu/therm) \* 0.8)]

= 8,923 therms

***Heat loss reduction through the roof***

∆Qr = Qr,s – Qr,d

= (1/Rr) \* Ar \* [(Tr,s – Toa) – (Tr,d – Toa)]

= (1/Rr) \* Ar \* (Tr,s – Tr,d)

Where:

Qr,s = roof heat loss for stratified space

Qr,d = roof heat loss for destratified space

Rr = overall thermal resistance through the roof (hr \* ft2 \* oF / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

|  |  |  |
| --- | --- | --- |
| **Thermal Resistance Factor (R-Factor) for Roof** | **Retrofit[[6]](#footnote-6)** | **New Construction[[7]](#footnote-7)**  **(2010 or newer)** |
| Rr | 10.0 (hr \* ft2 \* oF / Btu) | 20.0 (hr \* ft2 \* oF / Btu) |

Ar = roof area (ft2)

= user input

= can be approximated with floor area

Toa = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

Tr,s = indoor temperature at roof deck, stratified case (oF)

= Actual. If unknown, use the following equation

= ms \* hr + Tf,s

hr = ceiling height/roof deck (ft)

ms = estimated heat gain per foot elevation, stratified case (oF/ft)

= 0.8 oF/ft

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[[8]](#footnote-8),[[9]](#footnote-9). Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 oF/ft heat gain.

Tf,s = estimated floor temperature, stratified case (oF)

= Ttstat – ms \* htstat

= Ttstat – 4 oF

Ttstat = temperature set point at the thermostat

htstat = vertical distance between the floor and the thermostat, assumed 5ft

Tr,d = indoor temp at roof, destratified case

= actual value, or may be estimated using the following:[[10]](#footnote-10),[[11]](#footnote-11)

= Ttstat + 1 oF

For Example:

For a 50,000 ft2 warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 oF. No further measured values available.

∆Qr = (1/Rr) \* Ar \* (Tr,s – Tr,d) = (1/Rr) \* Ar \* [(ms \* hr + Ttstat – 4 oF) – (Ttstat + 1 oF)]

= (1/Rr) \* Ar \* [(0.8oF/ft \* hr) – 5 oF]

= 1/(10 hr \* ft2 \* oF / Btu) \* (50,000 ft2) \* [(0.8oF/ft \* 30 ft) – 5 oF]

= 95,000 Btu/hr

***Heat loss reduction through exterior walls***

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%.[[12]](#footnote-12)

∆Q\_w = Qw,s – Qw,d

= (1/Rw) \* Aw \* (Tw,s – Tw,d)

Where:

Rw = overall thermal resistance through the exterior walls (hr \* ft2\* oF / Btu)

= Actual or estimated based on construction type[[13]](#footnote-13). If unknown, assume the following

|  |  |  |
| --- | --- | --- |
| Thermal Resistance Factor (R-Factor) for Wall | Retrofit[[14]](#footnote-14) | New Construction[[15]](#footnote-15)  (2010 or newer) |
| Rw | 6.5 (hr \* ft2 \* oF / Btu) | 13.0 (hr \* ft2 \* oF / Btu) |

Aw = area of exterior walls (ft2)

= user input

Tw,s = average indoor air temperature for wall heat loss, stratified case

= If actual Tr,s measurement is available[[16]](#footnote-16)

= [(Tr,s \* ha) + (Ttstat \* hb)] / hr

ha = vertical distance between the heat source and the ceiling

hb = vertical distance between the floor and the heat source

= Otherwise, use the linear stratification equation at average space height, see definition above.

= ms \* (hr / 2) + Tf,s

= ms\* (hr / 2) + (Ttstat – 4)

Tw,d = average indoor air temperature for wall heat loss, destratified case

= Ttstat + 0.5

= conservative estimate using engineering judgment based on the same assumption used for Tr,f estimate.

For Example:

For a 50,000 ft2 warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 oF and a measured temperature at the ceiling of 85 oF and unit heaters located 10 feet from the roof:

∆Qw = (1/Rw) \* Aw \* (Tw,s – Tw,d)

= (1/Rw) \* Aw w\* [([(Tr,s \* ha) + (Ttstat \* hb)] / hr) – (Ttstat + 0.5 oF)]

= 1/(6.5 hr\*ft2\*oF/Btu) \* (50,000ft2) \* [([(85oF \* 10ft) + (65 oF \* 20ft)] / 30ft) – (65 + 0.5 oF)]

= 1/(6.5 hr\*ft2\*oF/Btu) \* (50,000ft2) \* (71.7 oF – 65.5 oF)

= 51,282 Btu/hr

(example deltaQ\_w)

***Measure eligibility check***

Use the following algorithm to verify a fan system is sufficiently sized to destratify air across the entire area.

Effective area, Aeff, is the area over which a fan or a group of fans can be expected to effectively destratify a space. If Aeff is less than the roof area, Ar, a custom analysis approach should be followed to account for the change in the effectiveness of the system. In lieu of more detailed studies, effective area is defined based on the measured results from an Enbridge Gas field study in which the area a fan was expected to effectively destratify was equal to 5 times the fan diameter[[17]](#footnote-17). Effective area, is calculated as follows:

Aeff = [π \* (5\*Dfan)2) / 4] \* Nfan

= 6.25 \* π \* Dfan2 \* Nfan

Where:

Aeff = the effective area fan area on the floor (ft2)

Dfan = fan diameter

Nfan = the number of fans

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-DSFN-V01-160601

1. Kosar, Doug, “1026: Destratification Fans – Public Project Report,” Nicor Gas, Emerging Technology Program (Oct 2014): 16 [↑](#footnote-ref-1)
2. Kosar, Doug, “1026: Destratification Fans – Public Project Report,” Nicor Gas, Emerging Technology Program (Oct 2014): 16 [↑](#footnote-ref-2)
3. Consistent with both 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008 and GDS Associates, Inc, “Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures,” New England Stat Program Working Group (June 2007), p30. [↑](#footnote-ref-3)
4. Costs were obtained from manufacturer interviews and are based off of average or typical prices for base model HVLS fans. Costs include materials and labor to install the fans and tie fans into an existing electrical supply located near the fan. [↑](#footnote-ref-4)
5. These were calculated at various base temperatures using TMY3 data and adjusted to make consistent with the 30 year normal data used elsewhere. For more information see ‘Destratification Fan Workpaper’; Robert Irmiger, Gas Technology Institute, 9/6/2015. [↑](#footnote-ref-5)
6. ANSI/ASHRAE/IESNA 100-1995, “Energy Conservation in Existing Buildings,” ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used. [↑](#footnote-ref-6)
7. ANSI/ASHRAE/IESNA Standard 90.1-2007, “Energy Standard for Buildings Except Low-Rise Residential Buildings,” ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5 [↑](#footnote-ref-7)
8. Kosar, Doug, “1026: Destratification Fans – Public Project Report,” Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center. [↑](#footnote-ref-8)
9. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain. [↑](#footnote-ref-9)
10. 12. Kosar, Doug, “1026: Destratification Fans – Public Project Report,” Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center. [↑](#footnote-ref-10)
11. 13. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48. [↑](#footnote-ref-11)
12. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 51 [↑](#footnote-ref-12)
13. Because heat loss through the walls is estimated using the average space temperature pre- and post- destratification. There are a number of factors that can impact the average space temperature causing deviations from estimates of many degrees in some cases. As such, it is recommended that a conservative value for the thermal resistance through the walls, Rw, be used. A recommended method for determining R­w would be to use the highest R-value for the wall space, neglecting lower R-values associated with windows, thermal bridges, etc. [↑](#footnote-ref-13)
14. ANSI/ASHRAE/IESNA 100-1995, “Energy Conservation in Existing Buildings,” ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used. [↑](#footnote-ref-14)
15. ANSI/ASHRAE/IESNA Standard 90.1-2007, “Energy Standard for Buildings Except Low-Rise Residential Buildings,” ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5 [↑](#footnote-ref-15)
16. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48 [↑](#footnote-ref-16)
17. Enbridge Gas Distribution, Inc., “Big Fans Deliver Big Bonus,” (Aug 2007) https://www.enbridgegas.com/businesses/assets/docs/hunter\_douglas\_case\_study.pdf. Additionally, multiple utilities have adopted this definition in their programs in including Enbridge Gas and Consumers Energy. [↑](#footnote-ref-17)