From: Dave Bohac
To: RULES, DLI (DLI)
Cc: Russ Landry
Subject: CEE comments for amendment to rules governing the adoption of ANSI/ASHRAE Standard 90.1-2019
Date: Thursday, February 24, 2022 9:32:57 AM
Attachments: CommercialEnergyCode_Air_Barrier_Testing_PublicComments_CEE_2022_02_24.xps.pdf

Ms. Spuckler-

I have attached a letter in response to the Request for Comments on possible amendment to rules governing the adoption of ANSI/ASHRAE Standard 90.1-2019 Energy Standard for Building Except Low-Rise Residential Buildings, Minnesota Rules, Chapter 1323; Revisor's ID# R-04696 published in the State Register on October 25, 2021.

On behalf of the Center for Energy and Environment, I would like to thank you for your consideration of these comments.

Dave Bohac, P.E. | he/him
Director of Research
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Center for Energy and Environment

February 24, 2022

Amanda Spuckler
Department of Labor and Industry
443 Lafayette Road N.
St. Paul, MN 55155

Dear Ms. Spuckler & Other DLI Representatives,

This letter is in response to the *Request for Comments on possible amendment to rules governing the adoption of ANSI/ASHRAE Standard 90.1-2019 Energy Standard for Building Except Low-Rise Residential Buildings, Minnesota Rules, Chapter 1323; Revisor's ID# R-04696* published in the State Register on October 25, 2021. I support the changes that Diana Burk proposed during the TAG meetings process to section 5.4.3.1 that include lowering the approval threshold for air barrier testing to 0.25 cfm/ft^2 under a pressure differential of 0.3 in. of water. I understand that during TAG discussions, a concern was expressed about whether warehouse and other large open facilities would have trouble meeting this 0.25 cfm/ft^2 threshold (as opposed to the 0.40 cfm/ft^2 threshold in the unamended document). The results from whole building envelope leakage tests of new commercial buildings that others and I have conducted indicate that commercial buildings can achieve a leakage rate of 0.25 cfm/ft^2 or less. In addition, I recommend adding ASTM E3158 as a method for conducting the required air leakage test.

<u>Comments in Support of Proposed Amendment to Section 5.4.3.1</u>
Extensive tests of commercial building envelope leakage have been conducted over the past 10+ years that support a threshold of 0.25 cfm/ft^2 under a pressure differential of 0.3 in. of water. The 2014 ASHRAE research reported that all six buildings with an enclosure consultant and quality assurance program met a leakage threshold of 0.25 cfm/ft^2. Marceau and Shrode noted that only 3% of the 196 military buildings tested did not meet the 0.25 cfm/ft^2 threshold. About half the commercial and institutional buildings met a threshold of 0.25 cfm/ft^2 even though the requirement was 0.40 cfm/ft^2. They concluded that building leakage has decreased since the testing requirement went into effect and that buildings were already able to meet a 0.30 cfm/ft^2 threshold. Tests of eight warehouses showed that seven buildings met a threshold of 0.25 cfm/ft^2 and three were less than 0.10 cfm/ft^2. For the one warehouse with a leakage greater than 0.25 cfm/ft^2 the excess leakage was due to code-required operable louvered vents. Center for Energy and Environment's (CEE) third-party tests of large buildings found only two of ten with leakage greater than 0.25 cfm/ft^2. One building had difficulty controlling indoor humidity and was subsequently sealed. The second had incomplete portions of the envelope. These findings indicate that all commercial buildings, including large and open buildings, can meet an envelope leakage threshold of 0.25 cfm/ft^2.

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- The 2014 ASHRAE research project (1478-RP) conducted tests on 16 recently constructed U.S. commercial buildings. The average whole building leakage was 0.29 cfm/ft^2 with a range of 0.06 to 0.74 cfm/ft^2. Half the buildings had a leakage less than 0.25 cfm/ft^2. All six buildings designed with an enclosure consultant and quality assurance program met a leakage threshold of 0.25 cfm/ft^2. IR surveys identified areas with significant envelope air leakage for the buildings with leakage greater than 0.25 cfm/ft^2.
- Marceau and Shrode presented results from 276 large building envelope leakage tests at the ASHRAE Buildings XIV conference.[1] Key findings included the following.
    - Of the 196 military buildings, only six did not pass the USACE requirement of 0.25 cfm/ft^2. There is a slight decrease in air leakage for larger buildings.
    - The 2015 Washington State energy code specified a threshold of 0.4 cfm/ft^2 and the 2015 Seattle energy code specified 0.30 cfm/ft^2. For buildings that did not meet the threshold, the codes required a visual air barrier inspection and leaks sealed to the extent practicable. A total of 80 buildings were tested in the Seattle/Washington state area. Most non-military buildings had to meet a threshold of 0.40 cfm/ft^2. The average leakage of the commercial buildings was 0.29 cfm/ft^2 and the average for the institutional buildings was 0.23 cfm/ft^2. This shows that even though the buildings only had to achieve a leakage less than 0.40 cfm/ft^2, many met a threshold of 0.25 cfm/ft^2.
    - Two important items for meeting the leakage requirement were (1) properly installed door gaskets and (2) frequent site visits to review installation.
    - The authors concluded that the data show that the measured leakage rate has generally decreased since energy code requirements for testing have come into effect. It is already possible to meet Seattle's requirement of 0.3 cfm/ft^2.
- Third-party envelope leakage tests of three warehouses with floor areas of 242,000, 810,000, and 753,000 square feet resulted in leakages of 0.05, 0.05, and 0.48 cfm/ft^2. The high leakage of 0.48 cfm/ft^2 was due to leakage through code-required operable louvered vents.
- Recent tests of three new warehouses with floor areas of 35,000, 42,000, and 37,000 square feet resulted in measured envelope leakage of 0.21, 0.21, and 0.24 cfm/ft^2.

The Center for Energy and Environment (CEE) has conducted third-party commercial building envelope leakage tests on 10 buildings over the past 10 years (see table below).[2] The buildings were recently constructed unless otherwise noted. Only two needed to meet a required leakage threshold of 0.25 cfm/ft^2. Eight buildings had a leakage less than 0.25 cfm/ft^2. The Texas college building with a leakage greater than 0.25 cfm/ft^2 was not able to achieve acceptable indoor humidity. It was tested prior to envelope sealing, which reduced

[1] M. Marceau and A. Shrode, 2019. *Analysis and Lessons Learned from Whole-Building Air Leakage Testing of 276 Buildings*. Thermal Performance of the Exterior Envelopes of Whole Buildings XIV International Conference. December 9–12, 2019.

[2] This does not include buildings tested for the ASHRAE research project.

the leakage to 0.21 cfm/ft². The hotel's lower level with high leakage was not complete at the time of the test. The upper level had a leakage of 0.21 cfm/ft² and the lower-level leakage was 0.48 cfm/ft².

Leakage (cfm/ft²)	Floor Area (ft²)	Year Tested	Notes
0.29	71,740	2020	Texas college classroom building #1. The HVAC system was not able to achieve acceptable indoor humidity. Envelope sealing was performed that reduced the leakage to 0.21 cfm/ft².
0.24	29,767	2020	Texas college classroom building #2
0.09	40,500	2020	Minnesota warehouse
0.30	118,262	2018	Colorado hotel. The building was required to meet a leakage threshold of 0.25 cfm/ft². Additional tests found that the completed upper level of the building had a leakage of 0.21 cfm/ft². The incomplete lower level had a leakage of 0.48 cfm/ft².
0.15	19,852	2017	Minnesota retail building[3]
0.06	50,500	2017	Minnesota medical building[3]
0.15	600,000+	2015	USACE hospital. Required to meet 0.25 cfm/ft²
0.13	34,563	2015	Iowa wellness center (pool, gym, and therapy rooms; existing)
0.15	79,982	2014	Minnesota warehouse (older)
0.23	12,155	2013	Minnesota office (older with leaky windows)

CEE recently completed a DOE-funded, six-state study of envelope leakage of new, low-rise multifamily buildings. While the residential code applies to these buildings, the results provide insights to the buildings' ability to meet the code-required leakage threshold. The whole building leakage of all 12 Minnesota buildings was less than the code required threshold of 3.0 ACH50. The leakage ranged from 0.95 ACH50 to 2.23 ACH50 and averaged 1.35 ACH50. The surface area normalized average leakage was 0.18 cfm/ft² for a pressure difference of 0.25 in. water, which is approximately equal to 0.23 cfm/ft² for a pressure difference of 0.30 in. water.

A CEE study, funded by the State of Minnesota, of large building leakage conducted whole building envelope leakage tests on seven commercial and institutional buildings built from

[3] Oak Ridge National Laboratory research project.

Center for Energy and Environment

1936 to 2007 with floor areas that ranged from 27,000 to 246,000 square feet. The air leakages ranged from 0.09 to 0.19 cfm/ft^2 for a pressure difference of 0.30 in. water.

Proposed Modification to Section 5.4.3.1

I recommend that the first sentence of section 5.4.3.1 Whole-Building Air Leakage be modified to allow *ASTM E3158-18 Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building* be included as a test method. The modified sentence would read:

> Whole-building pressurization testing shall be conducted in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E3158, or ASTM E1827 by an independent third party.

ASTM E3158 was developed for whole building testing of large buildings. It describes methods to address issues that occur for larger buildings that are not specified by E779.

On behalf of Center for Energy and Environment, I would like to thank you for your consideration of these comments.

DocuSigned by:
Dave Bohac, P.E.
D59C13EC4276448...

David Bohac, PE
Director of Research, Center for Energy and Environment

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From: Russ Landry
To: RULES, DLI (DLI)
Cc: Jamie Fitzke; Rick Hermans; Elizabeth K. Tomlinson; Stotko, Aaron
Subject: CEE and Minnesota Chapter of ASHRAE Comments on Commercial Energy Code Amendment for Energy Recovery Ventilation
Date: Monday, April 4, 2022 9:43:32 AM
Attachments: CommercialEnergyCode ERVamendment PublicComments MnASHRAE CEE 04 04 22.pdf
Willdan ERV Cost Results v3.xlsx

Ms. Spuckler-

I have attached a letter and supporting spreadsheet in response to the Request for Comments on possible amendment to rules governing the adoption of ANSI/ASHRAE Standard 90.1-2019 Energy Standard for Building Except Low-Rise Residential Buildings, Minnesota Rules, Chapter 1323; Revisor's ID# R-04696 published in the State Register on October 25, 2021.

On behalf of the Minnesota Chapter of ASHRAE and Center for Energy and Environment, I would like to thank you for your consideration of the attached comments asking that the amendment discussed at the 3/30/2021 TAG meeting to delete Table 6.5.6.1.2-2 and amend Table 6.5.6.1.2-1 not be incorporated into the final rules. I have also attached a spreadsheet that was prepared by Willdan (at the request of myself and the leadership of the Minnesota chapter of ASHRAE) confirming the cost-effectiveness of the unamended set of requirements in these tables.

Thank you.

Russ Landry, P.E., LEED AP | he/him
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Center for Energy and Environment

April 4, 2022

Amanda Spuckler
Department of Labor and Industry
443 Lafayette Road N.
St. Paul, MN 55155

Dear Ms. Spuckler & Other DLI Representatives,

This letter is in response to the *Request for Comments on possible amendment to rules governing the Adoption of ANSI/ASHRAE Standard 90.1-2019 Energy Standard for Building Except Low-Rise Residential Buildings, Minnesota Rules, Chapter 1323; Revisor's ID# R-04696* published in the State Register on October 25, 2021. On behalf of both the Minnesota Chapter of ASHRAE and the Center for Energy and Environment, I would like to thank you for your consideration of these comments asking that the amendment to Table 6.5.6.1.2-1 and deletion of Table 6.5.6.1.2-2 Exhaust energy recovery requirements for ventilation systems discussed by the TAG on 3/30/2022 not be incorporated into the final rules.

This set of amendments related to Energy Recovery Ventilation (ERV) was discussed at the final meeting of the TAG group on 3/30/2022, apparently without the submission of a formal code change proposal form and without any documentation to support the orally reported concern about cost-effectiveness. As detailed below, the leadership of the Minnesota Chapter of ASHRAE and CEE believe that neither of these tables (or the reference to them) should be amended both because they are cost-effective as written within the standard and because this would provide better uniformity with long-standing requirements in national codes.

Cost-Effectiveness of ERV Requirements in Tables 6.5.6.1.2-1 and 6.5.6.1.2-2. The cost-effectiveness of the requirements in these tables (which vary by climate zone, system size, and percentage of outdoor air in each system) was carefully evaluated by a group of national experts before the Table 6.5.6.1.2-1 (with the same values)[1] were first introduced in ASHRAE Standard 90.1-2010 after a consensus-based standards development process agreed upon them. Then a similar, rigorous nationally organized evaluation and consensus decision was made to add Table 6.5.6.1.2-2 into the 2013 version of ASHRAE Standard 90.1 with a more stringent set of requirements for only those systems that operate nearly continuously (8,000 or more of the 8,760 hours in a year). Both of these tables were accepted by the International Code Council and incorporated into every version of the International Energy Conservation Code that was released after the respective ASHRAE 90.1 Standard, without alteration of the values in the tables. The number of manufacturers

[1] The only change between the table introduced in 90.1-2010 and the 90.1-2019 version was raising the size threshold for one of the ranges of percentage of outdoor air (making it slightly less stringent).

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offering ERVs and the number of equipment options has only grown in the ten years since the most recently introduced set of values (in Table 6.5.6.1.2-2) was found to be cost-effective on a national level, so it would seem unlikely that they would be any less cost-effective when the new rules go into effect in 2023. Therefore, it would seem that a rigorous local analysis should be needed to justify a Minnesota amendment to the values in these tables. However, no such analysis was provided to the TAG to justify this amendment.

Moreover, an analysis of local cost-effectiveness prepared in March of 2021 at the request of CEE and leadership of the Minnesota chapter of ASHRAE clearly shows that the ERV requirement thresholds detailed in Tables 6.5.6.1.2-1 and 6.5.6.1.2-2 in ASHRAE 90.1-2019 are cost-effective as written. This analysis is provided in a spreadsheet that was attached to the same emails as this letter. Note that the two different versions of fist cost used for the cost-effectiveness are based on whether or not the design/development team takes advantage of the ERV benefit of reduced loads on primary heating and cooling equipment. The reduced loads on other HVAC equipment (provided by preheating and precooling of outdoor ventilation air) allows other systems to be downsized significantly in the vast majority of applications.

Consistency with National Standards. The unamended versions of these two tables are consistent across ASHRAE Standard 90.1 (since 2010 for one table and 2013 for the other) and the International Energy Conservation Code (since 2012 for one table and 2015 for the other). Moreover, this specific requirement is one of the most energy-impactful single items in the energy code. Therefore, a high level of justification should be required for the proposed amendment's very significant departure from these two national model codes, which will also lead to much greater annual energy costs for a large number of buildings in Minnesota.

Another important consideration regarding consistency with the ASHRAE Standard 90.1-2019 is that this particular amendment's large impact on energy use is significant enough that it is likely to impact the state's requirement to certify equivalence of the state's commercial energy code with the latest version of ASHRAE 90.1, as required by federal statue. At a minimum, this amendment's impact is likely to require a greater degree of analysis to determine equivalence. It is also likely that the impact is significant enough to tip the balance in the final determination of equivalence.

Limited Due Process in TAG Meetings for This Amendment. While the TAG meetings for the adoption of ASHRAE 90.1-2019 as Minnesota's Commercial Energy Code were generally very well organized and systematically gave chances for input and consideration of the large number of amendments that were formally proposed, this particular amendment didn't seem to be given the same degree of careful consideration, despite it probably being the single most energy impactful amendment that was evaluated. First of all, this amendment was only orally proposed and then discussed during the group's final meeting, even though most other amendments had written versions of the amendments and supporting arguments distributed to TAG members well ahead of the meeting(s) at which they would be discussed. No written form of the amendment or supporting arguments were provided to the TAG. While the attached spreadsheet with a counter argument to the non-cost-effectiveness claim was provided to the TAG members for consideration, the informality of this amendment's consideration contributed to this spreadsheet only being provided to the TAG group very shortly before the 3/30/2021 meeting at which this item was discussed. While a majority of TAG members at the meeting did agree with the amendment orally proposed by John Smith, my recollection is that it was a slim majority agreeing with the amendment rather than the consensus described in the meeting notes. This was also the final meeting of the TAG group, so there was significant pressure for this amendment to be decided upon without taking time to carefully review and consider relevant information and arguments. I would also like to highlight that one of the TAG's key subject matter experts for this item, Julianne Lau of Mortenson, was absent from this meeting. Therefore, there were multiple factors leading to the TAG's majority recommendation not being based on the level of careful, balanced consideration that the TAG groups usually provide.

While we understand and greatly appreciate DLI's strong preference to generally not revisit technical details discussed by TAGs, we believe that the importance of this amendment justifies reconsideration by DLI staff and its commissioner. The proposed amendment would roll back a very energy impactful requirement that was proven to be cost-effective a decade before the new energy code will go into effect and has been standardized in both national model energy codes ever since. Moreover, the state's proposed departure from this standard is significant enough to jeopardize compliance with federal statute. Therefore, we ask that the Tables 6.5.6.1.2-1 and 6.5.6.1.2-2 in ASHRAE Standard 90.1 be left in their unamended form in the new Minnesota Energy Code, along with the references to these tables in the text.

On behalf of the Minnesota Chapter of ASHRAE and the Center for Energy and Environment, I would like to thank you for your consideration of these comments.

Russell Landry
Russ Landry, PE
Senior Mechanical Engineer, Center for Energy and Environment
Former President and Current Government Affairs Committee Member, Minnesota Chapter of ASHRAE
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rlandry@mncee.org

ERV Economic Analysis for Minnesota. Prepared by Willdan (Jim Douglas & Eddie Galindo; March 29, 2021)

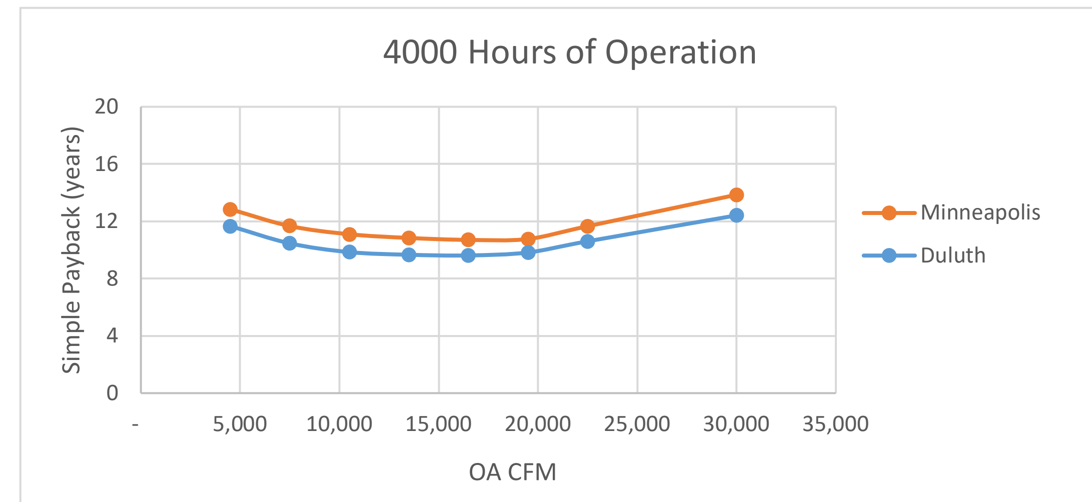
This version only considers the cost of adding ERV to the system (assuming that the rest of the HVAC equipment remains unchanged).

project	30,000 sq ft commercial, 20% window to wall ratio	
system	VAV with air cooled chiller and natural gas boiler	
air flow	30,000	cfm
heat recovery system cost	$ 5.00	per outside air cfm
utility electric tariff	$ 0.11	per kWh (demand, consumption blended)
utility natural gas tariff	$ 0.75	per therm (delivery and commodity)

Include plant capacity first cost savings? 0 (1=Yes, 0=No)

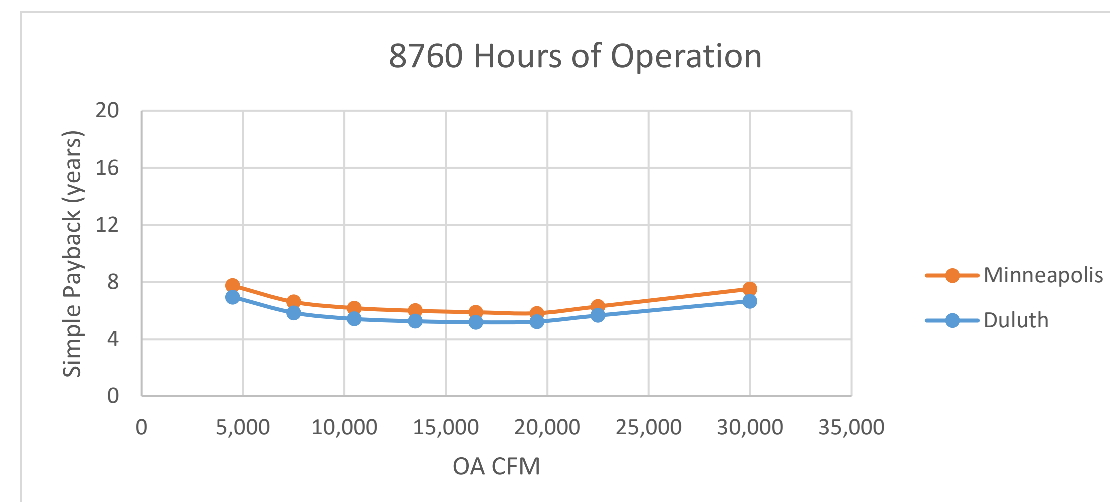
Duluth: 4000 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 1,928	$ 3,584	$ 5,330	$ 6,984	$ 8,577	$ 9,923	$ 10,607	$ 12,081
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Simple Payback	11.7	10.5	9.8	9.7	9.6	9.8	10.6	12.4

Minneapolis: 4000 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 1,752	$ 3,213	$ 4,731	$ 6,227	$ 7,708	$ 9,056	$ 9,649	$ 10,826
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Simple Payback	12.8	11.7	11.1	10.8	10.7	10.8	11.7	13.9



Duluth: 8760 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 3,237	$ 6,409	$ 9,691	$ 12,842	$ 15,919	$ 18,638	$ 19,885	$ 22,514
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Simple Payback	7.0	5.9	5.4	5.3	5.2	5.2	5.7	6.7

Minneapolis: 8760 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 2,906	$ 5,677	$ 8,502	$ 11,273	$ 14,016	$ 16,758	$ 17,889	$ 19,956
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Simple Payback	7.7	6.6	6.2	6.0	5.9	5.8	6.3	7.5



ERV Economic Analysis for Minnesota. Prepared by Willdan (Jim Douglas & Eddie Galindo; March 29, 2021)

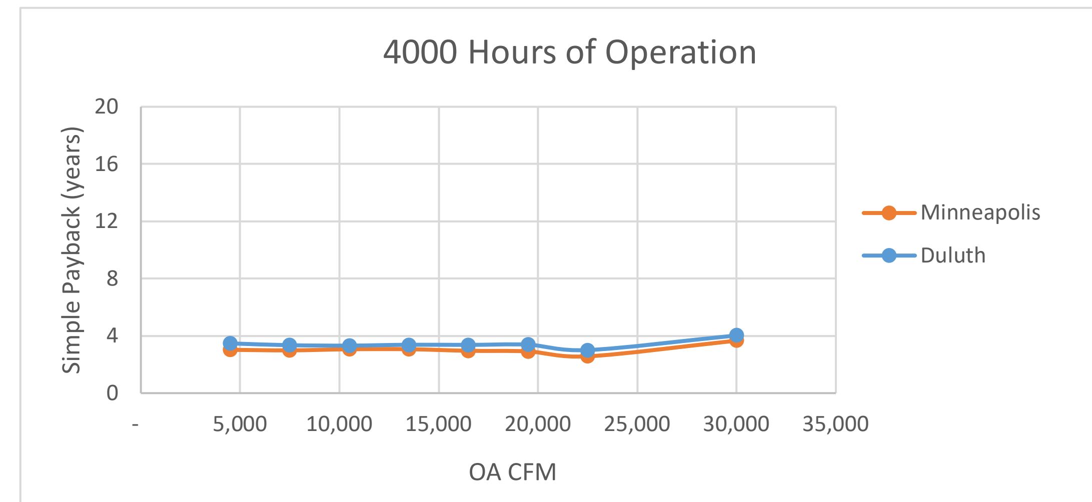
This version deducts heating and cooling plant cost savings from the cost to add ERV to the system.

project	30,000 sq ft commercial, 20% window to wall ratio	
system	VAV with air cooled chiller and natural gas boiler	
air flow	30,000	cfm
heat recovery system cost	$ 5.00	per outside air cfm
utility electric tariff	$ 0.11	per kWh (demand, consumption blended)
utility natural gas tariff	$ 0.75	per therm (delivery and commodity)

Include plant capacity first cost savings? 1 (1=Yes, 0=No)

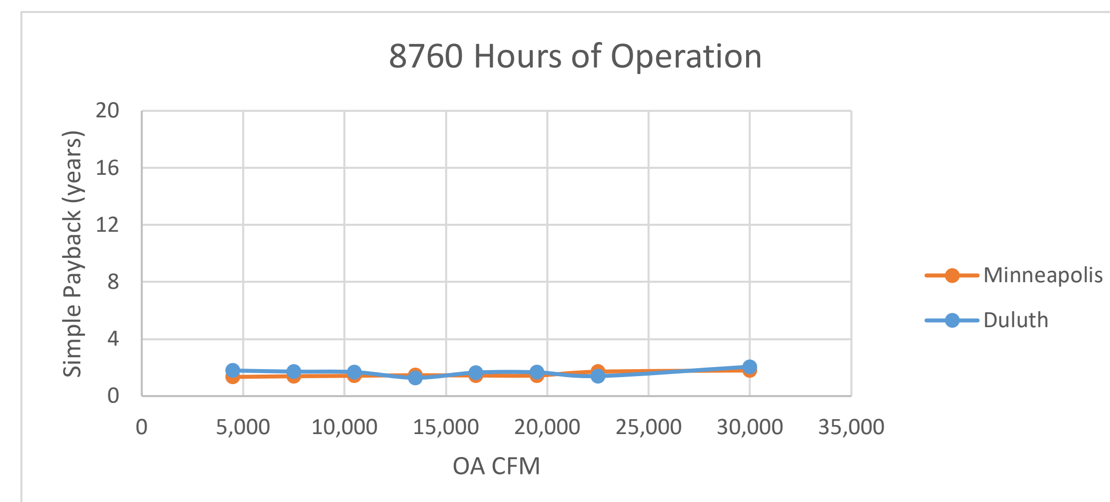
Duluth: 4000 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 1,928	$ 3,584	$ 5,330	$ 6,984	$ 8,577	$ 9,923	$ 10,607	$ 12,081
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ 15,800	$ 25,500	$ 34,800	$ 43,900	$ 53,600	$ 63,900	$ 80,600	$ 101,300
Simple Payback	3.5	3.3	3.3	3.4	3.4	3.4	3.0	4.0

Minneapolis: 4000 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 1,752	$ 3,213	$ 4,731	$ 6,227	$ 7,708	$ 9,056	$ 9,649	$ 10,826
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ 17,200	$ 27,900	$ 38,000	$ 48,400	$ 59,700	$ 71,100	$ 87,700	$ 110,300
Simple Payback	3.0	3.0	3.1	3.1	3.0	2.9	2.6	3.7



Duluth: 8760 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 3,237	$ 6,409	$ 9,691	$ 12,842	$ 15,919	$ 18,638	$ 19,885	$ 22,514
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ 16,700	$ 26,500	$ 36,200	$ 51,000	$ 56,200	$ 66,400	$ 84,600	$ 103,600
Simple Payback	1.8	1.7	1.7	1.3	1.7	1.7	1.4	2.1

Minneapolis: 8760 hours per year	**15%**	**25%**	**35%**	**45%**	**55%**	**65%**	**75%**	**100%**
OA CFM	**4,500**	**7,500**	**10,500**	**13,500**	**16,500**	**19,500**	**22,500**	**30,000**
Energy Cost Savings	$ 2,906	$ 5,677	$ 8,502	$ 11,273	$ 14,016	$ 16,758	$ 17,889	$ 19,956
Incremental Cost	$ 22,500	$ 37,500	$ 52,500	$ 67,500	$ 82,500	$ 97,500	$ 112,500	$ 150,000
Plant Capacity Savings	$ 18,600	$ 29,600	$ 40,400	$ 51,000	$ 62,300	$ 73,300	$ 81,900	$ 114,100
Simple Payback	1.3	1.4	1.4	1.5	1.4	1.4	1.7	1.8



ERV Economic Analysis for Minnesota. Prepared by Willdan (Jim Douglas & Eddie Galindo; March 29, 2021)

Condensing gas boiler? (yes = 85%, no = 100%) 85%

Index	Location	Hours	OA%	Run	Annual Electric Costs	Annual Natural Gas Costs (design boiler)	Pct Electric Cost Savings	Pct Natural Gas Cost Savings	Annual Electric Cost Savings	Annual Natural Gas Cost Savings	Annual Utility Cost Savings
1	DLH	4000	15	Base	$ 32,612	$ 9,913					
2	DLH	4000	15	Bundle	$ 32,768	$ 7,829	100%	79%	$ (156)	$ 2,084	$ 1,928
3	DLH	4000	25	Base	$ 32,094	$ 13,320					
4	DLH	4000	25	Bundle	$ 32,361	$ 9,468	101%	71%	$ (267)	$ 3,851	$ 3,584
5	DLH	4000	35	Base	$ 31,802	$ 16,931					
6	DLH	4000	35	Bundle	$ 32,200	$ 11,203	101%	66%	$ (398)	$ 5,728	$ 5,330
7	DLH	4000	45	Base	$ 32,105	$ 20,702					
8	DLH	4000	45	Bundle	$ 32,634	$ 13,189	102%	64%	$ (529)	$ 7,513	$ 6,984
9	DLH	4000	55	Base	$ 33,127	$ 24,598					
10	DLH	4000	55	Bundle	$ 33,774	$ 15,374	102%	63%	$ (647)	$ 9,224	$ 8,577
11	DLH	4000	65	Base	$ 34,718	$ 28,535					
12	DLH	4000	65	Bundle	$ 35,458	$ 17,871	102%	63%	$ (740)	$ 10,663	$ 9,923
13	DLH	4000	75	Base	$ 37,489	$ 32,433					
14	DLH	4000	75	Bundle	$ 38,252	$ 21,063	102%	65%	$ (763)	$ 11,370	$ 10,607
15	DLH	4000	100	Base	$ 45,141	$ 42,176					
16	DLH	4000	100	Bundle	$ 45,899	$ 29,337	102%	70%	$ (758)	$ 12,839	$ 12,081
17	MSP	4000	15	Base	$ 35,910	$ 8,596					
18	MSP	4000	15	Bundle	$ 35,861	$ 6,894	100%	80%	$ 49	$ 1,703	$ 1,752
19	MSP	4000	25	Base	$ 35,790	$ 11,416					
20	MSP	4000	25	Bundle	$ 35,749	$ 8,244	100%	72%	$ 41	$ 3,172	$ 3,213
21	MSP	4000	35	Base	$ 35,885	$ 14,459					
22	MSP	4000	35	Bundle	$ 35,898	$ 9,715	100%	67%	$ (13)	$ 4,744	$ 4,731
23	MSP	4000	45	Base	$ 36,636	$ 17,706					
24	MSP	4000	45	Bundle	$ 36,679	$ 11,435	100%	65%	$ (43)	$ 6,270	$ 6,227
25	MSP	4000	55	Base	$ 38,229	$ 21,134					
26	MSP	4000	55	Bundle	$ 38,263	$ 13,393	100%	63%	$ (34)	$ 7,742	$ 7,708
27	MSP	4000	65	Base	$ 40,201	$ 24,574					
28	MSP	4000	65	Bundle	$ 40,219	$ 15,501	100%	63%	$ (18)	$ 9,074	$ 9,056
29	MSP	4000	75	Base	$ 43,460	$ 27,950					
30	MSP	4000	75	Bundle	$ 43,393	$ 18,368	100%	66%	$ 67	$ 9,582	$ 9,649
31	MSP	4000	100	Base	$ 52,259	$ 36,419					
32	MSP	4000	100	Bundle	$ 51,850	$ 26,002	99%	71%	$ 409	$ 10,417	$ 10,826
33	DLH	8760	15	Base	$ 51,067	$ 10,597					
34	DLH	8760	15	Bundle	$ 51,327	$ 7,100	101%	67%	$ (260)	$ 3,497	$ 3,237
35	DLH	8760	25	Base	$ 49,945	$ 16,896					
36	DLH	8760	25	Bundle	$ 50,428	$ 10,005	101%	59%	$ (483)	$ 6,892	$ 6,409
37	DLH	8760	35	Base	$ 49,305	$ 23,650					
38	DLH	8760	35	Bundle	$ 50,046	$ 13,218	102%	56%	$ (741)	$ 10,432	$ 9,691
39	DLH	8760	45	Base	$ 49,525	$ 30,613					

40	DLH	8760	45	Bundle	$	50,532	$	16,764	102%	55%	$	(1,007)	$	13,849	$	12,842
41	DLH	8760	55	Base	$	50,744	$	37,686								
42	DLH	8760	55	Bundle	$	51,994	$	20,517	102%	54%	$	(1,250)	$	17,169	$	15,919
43	DLH	8760	65	Base	$	52,634	$	44,826								
44	DLH	8760	65	Bundle	$	54,098	$	24,724	103%	55%	$	(1,464)	$	20,102	$	18,638
45	DLH	8760	75	Base	$	56,629	$	51,891								
46	DLH	8760	75	Bundle	$	58,170	$	30,465	103%	59%	$	(1,541)	$	21,426	$	19,885
47	DLH	8760	100	Base	$	67,505	$	69,538								
48	DLH	8760	100	Bundle	$	69,079	$	45,450	102%	65%	$	(1,574)	$	24,088	$	22,514
49	MSP	8760	15	Base	$	55,659	$	9,209								
50	MSP	8760	15	Bundle	$	55,668	$	6,294	100%	68%	$	(9)	$	2,915	$	2,906
51	MSP	8760	25	Base	$	55,136	$	14,465								
52	MSP	8760	25	Bundle	$	55,242	$	8,682	100%	60%	$	(106)	$	5,783	$	5,677
53	MSP	8760	35	Base	$	55,010	$	20,142								
54	MSP	8760	35	Bundle	$	55,262	$	11,387	100%	57%	$	(252)	$	8,754	$	8,502
55	MSP	8760	45	Base	$	55,804	$	26,089								
56	MSP	8760	45	Bundle	$	56,185	$	14,435	101%	55%	$	(381)	$	11,654	$	11,273
57	MSP	8760	55	Base	$	57,742	$	32,212								
58	MSP	8760	55	Bundle	$	58,204	$	17,734	101%	55%	$	(462)	$	14,478	$	14,016
59	MSP	8760	65	Base	$	60,159	$	38,351								
60	MSP	8760	65	Bundle	$	60,648	$	21,105	101%	55%	$	(489)	$	17,247	$	16,758
61	MSP	8760	75	Base	$	64,403	$	44,408								
62	MSP	8760	75	Bundle	$	64,881	$	26,041	101%	59%	$	(478)	$	18,367	$	17,889
63	MSP	8760	100	Base	$	76,860	$	59,543								
64	MSP	8760	100	Bundle	$	76,859	$	39,588	100%	66%	$	1	$	19,955	$	19,956

ERV Economic Analysis for Minnesota. Prepared by Willdan (Jim Douglas & Eddie Galindo; March 29, 2021)

Base cooling system design capacity	400 sq ft per ton	Base cooling system cost	$ 2.00 per sq ft	Building size	30,000 sq ft
Base heating system design capacity	30 kBTU per sf	Base heating system cost	$ 2.00 per sq ft		

Index	Location	Hours	OA%	Model Run	Cooling peak (MBH)	Heating peak (MBH)	Cooling peak savings	Heating peak savings	Cooling peak savings (MBH)	Heating peak savings (MBH)	Cooling plant capacity sf/ton	Heating plant capacity BTU/sf	Cooling plant first cost*	Cooling plant first cost savings*	Heating plant first cost*	Heating plant first cost savings*	Total plant savings
1	DLH	4000	15	Base	752.7	-1029.6					478	34	$ 50,200		$ 68,600		
2	DLH	4000	15	Bundle	659.7	-885.1	88%	86%	93.1	-144.5	546	30	$ 44,000	$ 6,200	$ 59,000	$ 9,600	$ 15,800
3	DLH	4000	25	Base	871.9	-1302.6					413	43	$ 58,100		$ 86,800		
4	DLH	4000	25	Bundle	725.6	-1065.7	83%	82%	146.3	-237.0	496	36	$ 48,400	$ 9,700	$ 71,000	$ 15,800	$ 25,500
5	DLH	4000	35	Base	981.8	-1556.5					367	52	$ 65,500		$ 103,800		
6	DLH	4000	35	Bundle	788.2	-1230.7	80%	79%	193.6	-325.8	457	41	$ 52,500	$ 13,000	$ 82,000	$ 21,800	$ 34,800
7	DLH	4000	45	Base	1109.3	-1875.7					325	63	$ 74,000		$ 125,000		
8	DLH	4000	45	Bundle	866.7	-1459.4	78%	78%	242.6	-416.3	415	49	$ 57,800	$ 16,200	$ 97,300	$ 27,700	$ 43,900
9	DLH	4000	55	Base	1259.4	-2167.9					286	72	$ 84,000		$ 144,500		
10	DLH	4000	55	Bundle	963.0	-1661.2	76%	77%	296.4	-506.7	374	55	$ 64,200	$ 19,800	$ 110,700	$ 33,800	$ 53,600
11	DLH	4000	65	Base	1407.8	-2471.5					256	82	$ 93,900		$ 164,800		
12	DLH	4000	65	Bundle	1059.3	-1863.1	75%	75%	348.4	-608.4	340	62	$ 70,600	$ 23,300	$ 124,200	$ 40,600	$ 63,900
13	DLH	4000	75	Base	1563.3	-2777.4					230	93	$ 104,200		$ 185,200		
14	DLH	4000	75	Bundle	1067.5	-2064.2	68%	74%	495.8	-713.2	337	69	$ 71,200	$ 33,000	$ 137,600	$ 47,600	$ 80,600
15	DLH	4000	100	Base	1973.4	-3540.7					182	118	$ 131,600		$ 236,000		
16	DLH	4000	100	Bundle	1424.6	-2570.2	72%	73%	548.8	-970.5	253	86	$ 95,000	$ 36,600	$ 171,300	$ 64,700	$ 101,300
17	MSP	4000	15	Base	849.4	-1026.5					424	34	$ 56,600		$ 68,400		
18	MSP	4000	15	Bundle	739.8	-877.9	87%	86%	109.6	-148.6	487	29	$ 49,300	$ 7,300	$ 58,500	$ 9,900	$ 17,200
19	MSP	4000	25	Base	994.7	-1310.8					362	44	$ 66,300		$ 87,400		
20	MSP	4000	25	Bundle	819.3	-1068.6	82%	82%	175.4	-242.1	439	36	$ 54,600	$ 11,700	$ 71,200	$ 16,200	$ 27,900
21	MSP	4000	35	Base	1132.3	-1578.6					318	53	$ 75,500		$ 105,200		
22	MSP	4000	35	Bundle	896.2	-1244.6	79%	79%	236.1	-334.0	402	41	$ 59,700	$ 15,800	$ 83,000	$ 22,200	$ 38,000
23	MSP	4000	45	Base	1284.9	-1911.6					280	64	$ 85,700		$ 127,400		
24	MSP	4000	45	Bundle	987.4	-1484.2	77%	78%	297.5	-427.4	365	49	$ 65,800	$ 19,900	$ 98,900	$ 28,500	$ 48,400
25	MSP	4000	55	Base	1466.4	-2214.9					246	74	$ 97,800		$ 147,700		
26	MSP	4000	55	Bundle	1093.7	-1694.0	75%	76%	372.7	-520.9	329	56	$ 72,900	$ 24,900	$ 112,900	$ 34,800	$ 59,700
27	MSP	4000	65	Base	1651.5	-2516.3					218	84	$ 110,100		$ 167,800		
28	MSP	4000	65	Bundle	1199.0	-1903.4	73%	76%	452.5	-613.0	300	63	$ 79,900	$ 30,200	$ 126,900	$ 40,900	$ 71,100
29	MSP	4000	75	Base	1842.4	-2815.4					195	94	$ 122,800		$ 187,700		
30	MSP	4000	75	Bundle	1230.1	-2111.7	67%	75%	612.2	-703.7	293	70	$ 82,000	$ 40,800	$ 140,800	$ 46,900	$ 87,700
31	MSP	4000	100	Base	2354.6	-3566.9					153	119	$ 157,000		$ 237,800		
32	MSP	4000	100	Bundle	1640.2	-2627.7	70%	74%	714.4	-939.2	219	88	$ 109,300	$ 47,700	$ 175,200	$ 62,600	$ 110,300
33	DLH	8760	15	Base	740.3	-731.9					486	24	$ 49,400		$ 48,800		
34	DLH	8760	15	Bundle	647.5	-574.3	87%	78%	92.8	-157.6	556	19	$ 43,200	$ 6,200	$ 38,300	$ 10,500	$ 16,700
35	DLH	8760	25	Base	860.0	-1035.8					419	35	$ 57,300		$ 69,100		
36	DLH	8760	25	Bundle	713.7	-783.9	83%	76%	146.3	-251.8	504	26	$ 47,600	$ 9,700	$ 52,300	$ 16,800	$ 26,500
37	DLH	8760	35	Base	971.4	-1331.1					371	44	$ 64,800		$ 88,700		
38	DLH	8760	35	Bundle	777.0	-982.8	80%	74%	194.5	-348.3	463	33	$ 51,800	$ 13,000	$ 65,500	$ 23,200	$ 36,200
39	DLH	8760	45	Base	1298.0	-1693.1					277	56	$ 86,500		$ 112,900		
40	DLH	8760	45	Bundle	986.9	-1239.4	76%	73%	311.2	-453.7	365	41	$ 65,800	$ 20,700	$ 82,600	$ 30,300	$ 51,000
41	DLH	8760	55	Base	1253.3	-1958.9					287	65	$ 83,600		$ 130,600		
42	DLH	8760	55	Bundle	952.3	-1417.5	76%	72%	301.0	-541.4	378	47	$ 63,500	$ 20,100	$ 94,500	$ 36,100	$ 56,200

43	DLH	8760	65	Base	1404.6	-2264.9					256	75	$ 93,600		$ 151,000		
44	DLH	8760	65	Bundle	1049.1	-1625.1	75%	72%	355.5	-639.8	343	54	$ 69,900	$ 23,700	$ 108,300	$ 42,700	$ 66,400
45	DLH	8760	75	Base	1852.6	-2639.6					194	88	$ 123,500		$ 176,000		
46	DLH	8760	75	Bundle	1337.4	-1885.1	72%	71%	515.2	-754.6	269	63	$ 89,200	$ 34,300	$ 125,700	$ 50,300	$ 84,600
47	DLH	8760	100	Base	1985.4	-3330.0					181	111	$ 132,400		$ 222,000		
48	DLH	8760	100	Bundle	1417.1	-2343.8	71%	70%	568.2	-986.2	254	78	$ 94,500	$ 37,900	$ 156,300	$ 65,700	$ 103,600
49	MSP	8760	15	Base	837.8	-740.3					430	25	$ 55,900		$ 49,400		
50	MSP	8760	15	Bundle	721.5	-579.4	86%	78%	116.3	-160.9	499	19	$ 48,100	$ 7,800	$ 38,600	$ 10,800	$ 18,600
51	MSP	8760	25	Base	993.4	-1054.6					362	35	$ 66,200		$ 70,300		
52	MSP	8760	25	Bundle	806.3	-797.0	81%	76%	187.2	-257.6	447	27	$ 53,800	$ 12,400	$ 53,100	$ 17,200	$ 29,600
53	MSP	8760	35	Base	1137.0	-1360.8					317	45	$ 75,800		$ 90,700		
54	MSP	8760	35	Bundle	888.1	-1004.2	78%	74%	248.9	-356.6	405	33	$ 59,200	$ 16,600	$ 66,900	$ 23,800	$ 40,400
55	MSP	8760	45	Base	1253.9	-1698.5					287	57	$ 83,600		$ 113,200		
56	MSP	8760	45	Bundle	937.4	-1250.2	75%	74%	316.5	-448.3	384	42	$ 62,500	$ 21,100	$ 83,300	$ 29,900	$ 51,000
57	MSP	8760	55	Base	1483.2	-2009.6					243	67	$ 98,900		$ 134,000		
58	MSP	8760	55	Bundle	1103.1	-1456.2	74%	72%	380.2	-553.5	326	49	$ 73,500	$ 25,400	$ 97,100	$ 36,900	$ 62,300
59	MSP	8760	65	Base	1665.5	-2325.2					216	78	$ 111,000		$ 155,000		
60	MSP	8760	65	Bundle	1218.8	-1671.6	73%	72%	446.7	-653.6	295	56	$ 81,300	$ 29,700	$ 111,400	$ 43,600	$ 73,300
61	MSP	8760	75	Base	1842.4	-2815.4					195	94	$ 122,800		$ 187,700		
62	MSP	8760	75	Bundle	1317.5	-2111.7	72%	75%	524.9	-703.7	273	70	$ 87,800	$ 35,000	$ 140,800	$ 46,900	$ 81,900
63	MSP	8760	100	Base	2357.4	-3424.7					153	114	$ 157,200		$ 228,300		
64	MSP	8760	100	Bundle	1655.2	-2417.2	70%	71%	702.1	-1007.5	217	81	$ 110,300	$ 46,900	$ 161,100	$ 67,200	$ 114,100

*Heating and cooling plant costs are assumed to vary proportionally with the size of the system.