Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

RE: MA APS Draft Comments 6/30/16

Massachusetts DOER,

Mitsubishi Electric applauds the DOER and the Commonwealth of Massachusetts for being so proactive in developing this important piece of legislation. It is truly groundbreaking and will undoubtedly set the stage for programs in other states.

The comments expressed in this letter are intended to help the MA DOER ensure that the calculation methodologies and equipment eligibility requirements are drafted in a way that accomplishes the overall goals and objectives of the Alternative Portfolio Standard and encourages the exclusive participation of the most efficient HVAC products available.

Mitsubishi Electric is a manufacturer of high quality inverter driven heat pump systems, also known as mini splits or Variable Refrigerant Flow (VRF) systems. Although Mitsubishi Electric manufactures both air-source and water-source heat pumps (ground source heat pumps), the comments presented in this paper are only in regards to the "Electric Motor Driven Air Source Heat Pump" APS Renewable Thermal Generation Unit (RTGU) classification.

Given that the Electric Motor Driven Air Source Heat Pump RTGU classification is broken into three size categories: small, intermediate, and large; each size category will be addressed individually since there are different program requirements and corresponding calculation methodologies for each.

Classification: Small

Qualifying Equipment Requirements

> "Meets the requirements of the Cold Climate Air Source Heat Pump Specification published by the Northeast Energy Efficiency partnerships as is listed on NEEP's website." (3(E)(1)(b)(i))

Mitsubishi Electric understands that the program should be limited to products that qualify for the Cold Climate Air Source Heat Pump Specification (ccASHP). The one issue that NEEP's specification fails to constrain is heating output (Btu/h) at 5°F. If a homeowner is buying a product that qualifies for the ccASHP Specification, they have a certain expectation that it will produce significant heat in extreme conditions. NEEP's ccASHP Specification provides verification that it works efficiently when it is cold, but it does not guarantee sufficient capacity. It is the burden of the installing contractor to cross reference the heating output listed on NEEP's ccASHP listing against the calculated heating load of the home.

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

The Massachusetts Clean Energy Center (MassCEC) also uses the NEEP ccASHP Specification for their Clean Heating & Cooling Program. They have added an additional requirement of 100% of the rated heating output at 5°F. This requirement provides an expectation by the end user of heating capacity at cold temperatures, as well as efficiency. Table 1 below illustrates what such an additional requirement would do to the list of qualifying products. There are 12 companies that have products listed on the NEEP ccASHP list. (Click here for complete ccASHP list) Combined, these companies have 937 products listed on the AHRI Variable Speed Mini-Split Heat Pump directory. Of these, only 101 or 11% are NEEP certified. When you add the 100% heating capacity requirement at 5°F, you reduce this number to 57, or 6%.

	AHRI Listed	NEEP Listed	% NEEP	MassCEC Listed	% Mass CEC	Maximum Output at 5°F
American Standard	68	0	0%	0	0%	N/A
Carrier	182	11	6%	7	4%	24,030
Daikin	96	17	18%	4	4%	21,600
Friederich	5	3	60%	3	60%	27,229
Fujitsu	97	20	21%	16	16%	25,500
Haier	28	8	29%	4	14%	20,500
LG	94	15	16%	2	2%	38,900
Mitsubishi	216	22	10%	20	9%	48,000
Panasonic	32	2	6%	1	3%	12,500
Toshiba-Carrier	21	3	14%	0	0%	8,752
Trane	98	0	0%	0	0%	N/A
Total	937	101	11%	57	6%	

Table 1: AHRI listed data for ductless air source heat pumps

Recommendation:
Maintain the requirement for product to be listed on NEEP's ccASHP list, but add the requirement for 100% heating capacity at 5°F as the Massachusetts CEC has done. This will provide assurance to homeowners that the equipment is efficient, but that they will have full capacity, as low as 5°F. The Massachusetts CEC has already created this list and published it in their Program Manual for the Clean Heating & Cooling Program. (Click here for link to Program Manual)

Alternative Wording to (3(E)(1)(b)(i)): Meets the requirements published in the Massachusetts CEC Air Source Heat Pump Program Manual of the Clean Heating & Cooling Program.

Sizing Requirements

"All ASHP RTGUs must be designed to supply 100% of a building's total annual heat load with no non-renewable supplemental heat source."(3(E)(1)(d))

Traditionally, air source heat pumps have been used for displacement of the home's heat source, not replacement of the heat source. The reason for this is the majority of homes in Massachusetts require more heating capacity than current products on the market can produce. Even with the introduction of products by various manufacturers that provide 100% capacity at 5°F, this still isn't enough capacity for the average home, without installing a combination of multiple multi-zone and single zone systems.

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

Surveying local contractors that complete a Manual J heat loss/heat gain calculation for every job, the average Massachusetts home has a cooling requirement of 20 BTU's per square foot and a heating requirement of 25 BTU's per square foot. Table 2 illustrates what this translates to for the typical home. The AEC formula uses a 1,500 ft^2 home as its baseline. For this type of home, there are several products that can achieve 37,500 BTU's at design temperatures. For larger homes however, this is not the case. To achieve 62,500 BTU's a homeowner would need to install several different systems. This will add much more cost to the installation, and very likely discourage the homeowner from pursuing this option. Lastly, to achieve 100% heating capacity for homes larger than 2,500 ft^2, homeowners would be significantly oversized for their cooling requirements.

Load Type	Average BTU Requirements	1500 ft^2 home	2500 ft^2 home
Heating	25 BTU's per 1 ft^2	37,500 BTU's	62,500 BTU's
Cooling	20 BTU's per 1 ft^2 (BTU's)	30,000 BTU's	50,000 BTU's

Table 2: Heating and Cooling Load of typical home

Recommendation:
Do not require 100% of design load. Require a minimum of 50% of design load and adjust AEC Multiplier accordingly. Table 3 illustrates how reducing the requirement for 100% of design load impacts the total heat displaced. When 50% of the required heating capacity is provided by the heat pump, 94% of the total non-renewable heat is displaced based on Boston weather BIN data. Adjusting the standard AEC Multiplier to a 50% load would result in a new multiplier of 2.8 for Boston. (See Appendix A for calculations)

Boston			
System Size	% of Total Load	% Displaced	Multiplier
6,000	17%	46%	1.4
12,000	33%	79%	2.4
18,000	50%	94%	2.8
24,000	67%	99%	3.0
30,000	83%	100%	3.0
36,000	100%	100%	3.0

Table 3: Effect of not providing 100% heating capacity at design temperature

Alternative Wording to (3(E)(1)(d)): "All ASHP RTGU's must be designed to supply a minimum of 50% of a building's total annual heat load with no non-renewable supplemental heat source."

Classification: Intermediate

In section (3)(I)(15), the calculation formula for intermediate VRF ASHP RTGU's appears appropriate for the technology and we have no comments or suggestions for this classification, however, clarification regarding the time interval for measurement and reporting of AEC's would provide better clarity to owners/end users.

Additionally, while the small ASHP RTGU classification has very stringent eligibility criteria, the intermediate classification doesn't appear to have any criteria listed at all. Does this imply that all VRF systems are eligible provided their nominal capacity puts them in this size classification?

Output Capacity Between 0.134 & 1.00 MMBtu/h [4]

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

Recommendation:
A suggestion for improvement would be to require VRF systems to be found in the AHRI Directory (www.ahridirectory.org) in order to be eligible for this size classification. Doing so will provide several benefits including the following:

- High and Low COP are required to be published in the directory (ie, 47°FDB/43°FWB, and 17°FDB/15°FWB).
- Equipment combinations found in the directory have been tested and are 3rd party verified.

Classification: Large

Refrigerant mass flow measurements in the field would be a difficult and costly endeavor. To get the desired accuracy, the cost of the flow meter, transmitter, and data acquisition hardware would likely be in the range of $12,000 to $15,000 per refrigerant system. The flow meter must be installed in the refrigerant circuit in a location where there is certain to be only single-phase refrigerant. Any chance of two-phase refrigerant will produce inaccurate and unreliable results. The presence of the flow meter in the refrigerant circuit can be a restriction, especially if improperly sized, and the resulting pressure drop will affect the performance of the system. The addition of a flow meter introduces new potential leak points in the refrigerant circuit. The flow meter and transmitter may be large and bulky, making them less than suitable for field installations.

Recommendation:
Appendix B shows the refrigerant mass flow measurement diagram and corresponding formula for calculating AEC's for large VRF ASHP RTGU's, while Appendix C show the airflow/delta T diagram and corresponding formula for large DX ASHP RTGU's.

Due to the complexities and potential downsides to system performance of mass flow measurement in the field, we would recommend the use of condenser airflow and delta T measurements for VRF systems for alignment and better comparison to conventional heat pumps. Given the variable nature of VRF condenser fans, there is potential to measure input power to the condenser fan for use as a proxy for airflow (would need to be calibrated in the field).

Conclusion
This legislation is precedent setting and is very likely to be a model for future legislation around the country. We want this program to succeed, but have concerns that some of the wording in the existing draft may prevent program eligibility of products in an unintended and significant way. Minor changes in wording and requirements can have a big impact on the success of this program.

Thank you to the DOER and the state of Massachusetts for your work on this important piece of legislation, Mitsubishi Electric looks forward to seeing the final draft and helping contribute to the success of this program.

Best Regards,

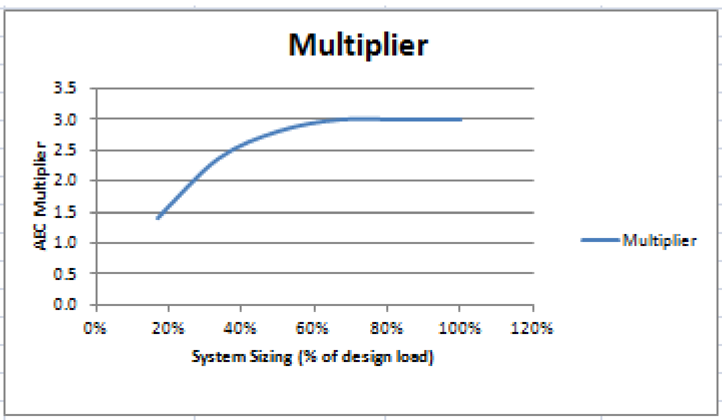
Eric Dubin | *Sr. Director of National Accounts and Utility Programs*
MITSUBISHI ELECTRIC COOLING & HEATING
Mobile: 617.939.1492 | Fax: 508.449.3811
edubin@hvac.mea.com | www.mehvac.com

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

Appendix A: BIN hours for Boston, MA

Bin (˚F)		Bin Avg (˚F)	Bin Hours	Load %	Run Hrs	Load (btu/h)
-5	0	-2.5	10	100%	10	36,000
0	5	2.5	9	100%	9	36,000
5	10	7.5	27	100%	27	36,000
10	15	12.5	77	74%	57	26,597
15	20	17.5	265	66%	176	23,910
20	25	22.5	284	59%	167	21,224
25	30	27.5	320	51%	165	18,537
30	35	32.5	707	44%	311	15,851
35	40	37.5	1060	37%	388	13,164
40	45	42.5	738	29%	215	10,478
45	50	47.5	763	22%	165	7,791
50	55	52.5	619	14%	88	5,104
55	60	57.5	772	7%	52	2,418

System Size	% of Total Load	% Displaced	Multiplier
6,000	17%	46%	1.4
12,000	33%	79%	2.4
18,000	50%	94%	2.8
24,000	67%	99%	3.0
30,000	83%	100%	3.0
36,000	100%	100%	3.0

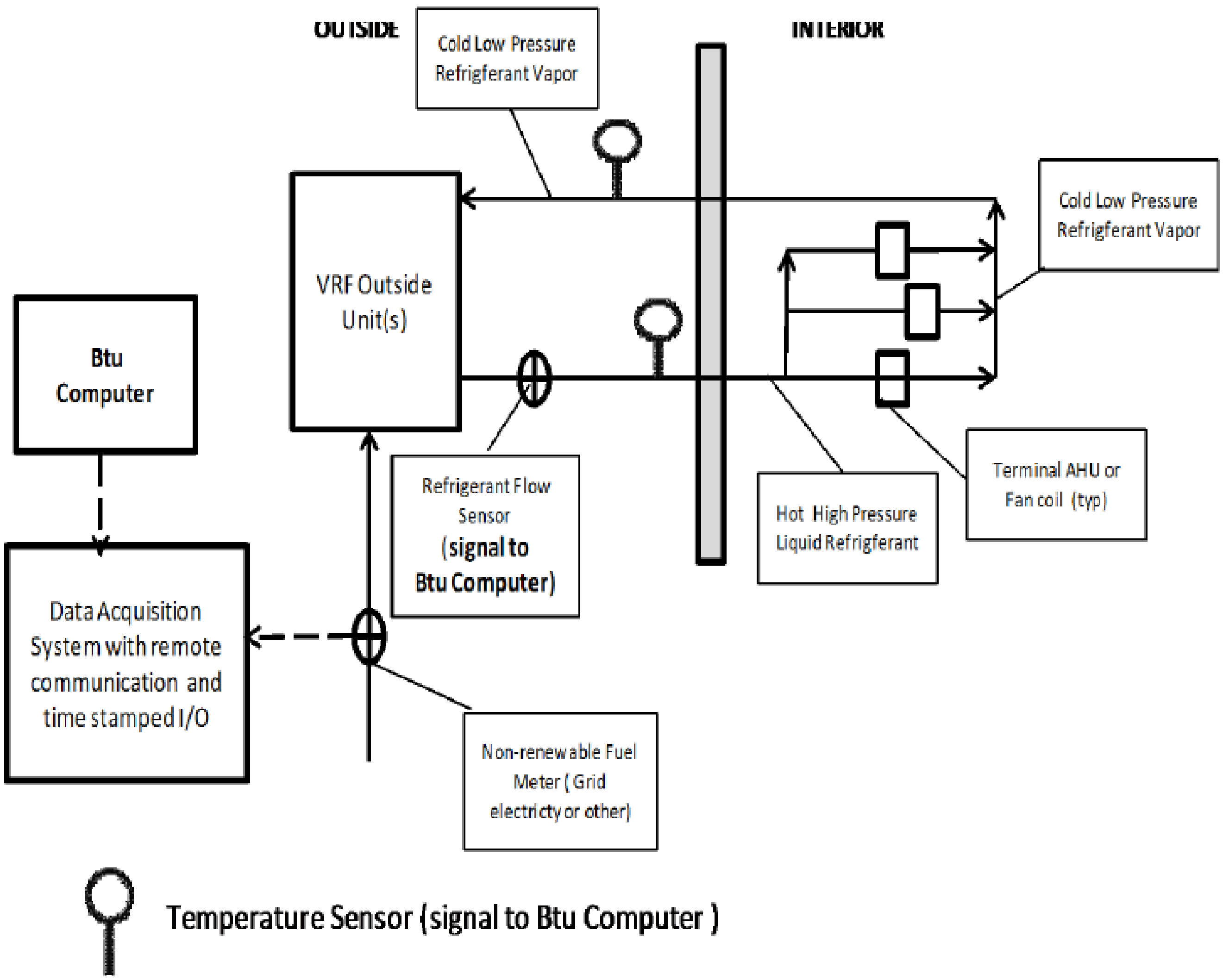


Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

Appendix B:

(16) Metering for Large, VRF AHSPs

Figure 9. Metering Diagram for a Large, VRF ASHP



Note: Only the components directly related to either the required APS metering or otherwise related to the terms of the AECs formula for VRF ASHPs are shown.

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

(17) AEC Formula for Large, VRF ASHPs

AECs = RH * M

Note: All terms are the cumulative as-metered values. Unless otherwise indicated, all units in MWh

Where:

RH = Renewable heat transferred from the ambient air to the system and is directly metered
The rate of renewable heat generated at any time is:

(SRF) * (Cp) * (RST-RRT) / 3.412E6 (Btu/MWh)

Where:

SRF = Supply refrigerant flow (lbs/hr)

Cp = Specific heat of the refrigerant supply (Btu/lb-deg F)

RST = Refrigerant supply temperature (°F)

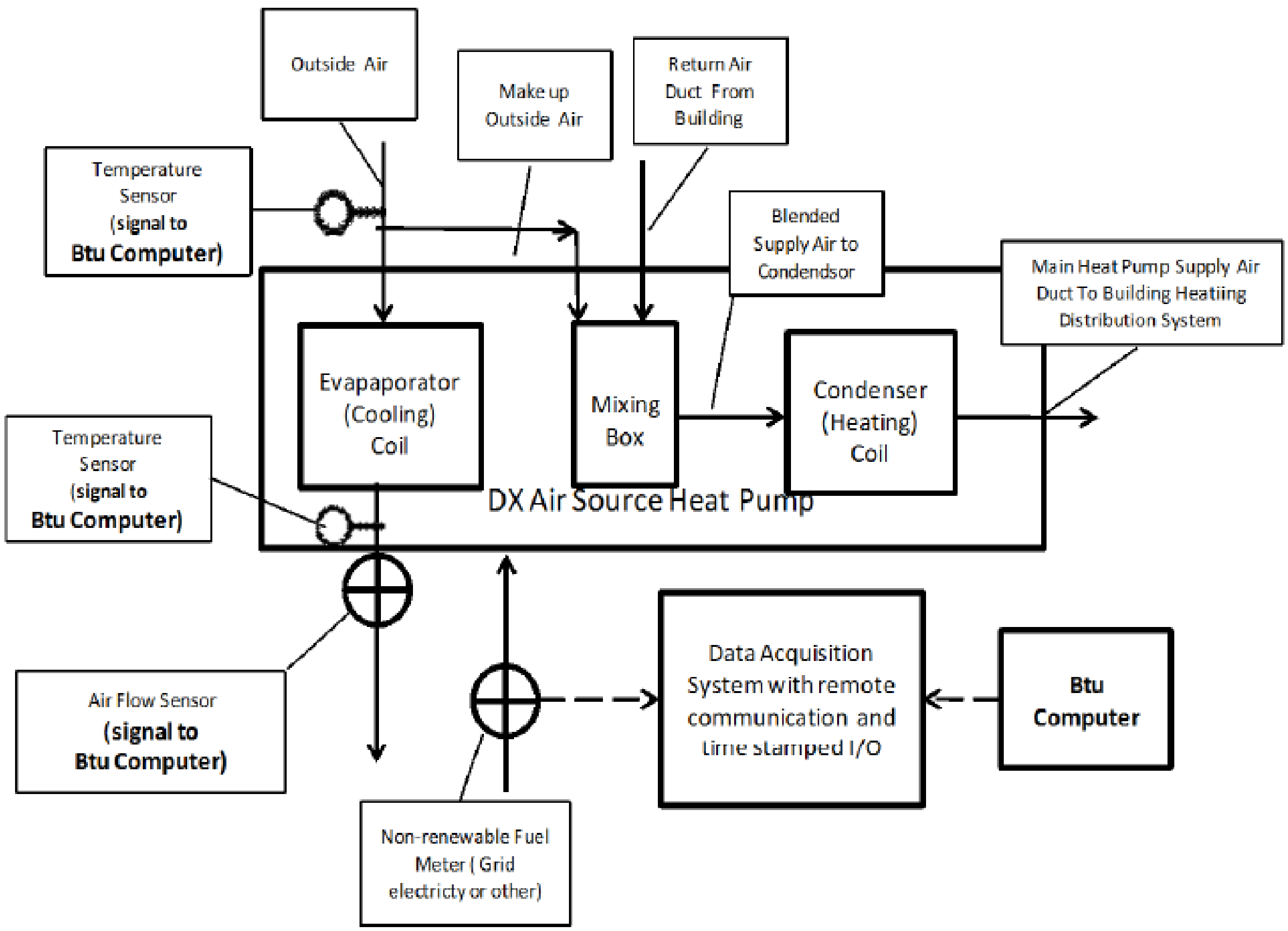
RRT = Refrigerant return temperature (°F)

Note: If the Cp of the RTGU refrigerant varies significantly as a function of the refrigerant temperature, the integration of this value over time will be done by the Btu computer software engine in time steps of less than or equal to five minutes each using a look up table or function as provided by the supplier of the refrigerant.

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

Appendix C:

Figure 7. Metering Diagram for a Large, DX ASHP



Note: Only the components directly related to either the required APS metering or otherwise related to the terms of the AECs formula for DX ASHPs are shown

Mitsubishi Electric U.S., Inc.
Cooling & Heating
150 Cordaville Road, Suite 110
Southborough, MA 01772
(508) 281-4095

(12) AEC Formula for Large, DX ASHPs

AECs = RH * M

Note: All terms are the cumulative as-metered values. Unless otherwise indicated, all units in MWh

Where:

RH = Renewable heat transferred from the ambient air to the system and is directly metered

The rate of renewable heat generated at any time is:

(EAF) * (Cp) * (ETA-LTA) / 3.412E6 (Btu/MWh)

Where:

EAF = Outside air flow rate (lbs/hr) through the Evaporator(s)

Cp = Specific heat of the outside air (Btu / lb-deg F)

ETA = Temperature of the outside air entering the evaporator section (°F)

LTA = Temperature of the outside air leaving the evaporator section (°F)