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July 25, 2017

Mr. Michael Judge
Renewable Energy Division Director
Massachusetts Department of Energy Resources

Dear Mr. Judge,

Following please find DCM Logic's comments on portions of the draft APS guidelines and regulations filed with the Secretary of the Commonwealth on June 2, 2017. We think it important to bring to your immediate attention that key portions of the draft as published are not in conformity with the enabling legislation, Chapter 251 of the Acts of 2014.

Our comments derive from monitoring real-world operation of over seventy boilers in over forty installations over the last four heating seasons, totaling hundreds of thousands of hours. We believe that our database, which includes boilers from multiple manufacturers, is quite likely the largest multi-season biomass boiler operation database in existence. The conclusions from it can be of substantial help to your Department in drafting regulations and guidelines that comply with the requirements set forth in relevant Commonwealth legislation, and form the basis for our comments that follow.

In hopes of assisting your review process, we are filing comments as early as feasible. It is possible that we will supplement or amend these comments again before the deadline. We welcome the opportunity to discuss our comments with you and your colleagues at your earliest convenience.

Respectfully submitted,

David N. Spindler

David N. Spindler, COO
DCM Logic LLC

DCM Logic Comments on *225 CMR 16.00 Alternative Energy Portfolio Standard (APS)* and *APS Guideline on Biomass, Biogas, and Biofuels for Eligible Renewable Thermal Generation Units*

DCM Logic finds that key portions of the MA Department of Energy Resources ("DOER") draft regulations regarding its biomass thermal programs, when viewed from the perspective of extensive real-world biomass boiler data, do not comport with relevant Massachusetts legislation.

Listed below are comments on specific sections of *225 CMR 16.00: Alternative Energy Portfolio Standard (APS)* [Draft] ("Regulations") and *APS Guideline on Biomass, Biogas and Biofuels for Renewable Thermal Generation Units* ("Guidelines"), referring (unless otherwise noted) to the draft versions filed with the Secretary of the Commonwealth on June 2, 2017. We examine these proposed regulations against real-world data in order to point out where the Regulations and Guidelines stand in opposition to certain portions of the Acts of 2014, Chapter 251 ("Act").

Section I: Comments on the Regulations

1. **Will a required volume of thermal storage achieve the Legislature's goal of minimizing boiler cycling?**

   Section 2(b)iii of the Act directs the Department to set

   > for eligible biomass, biogas and liquid biofuel technologies, requirements for thermal storage **or other means** to minimize any significant deterioration of efficiency or emissions due to boiler cycling, if feasible. [emphasis added]

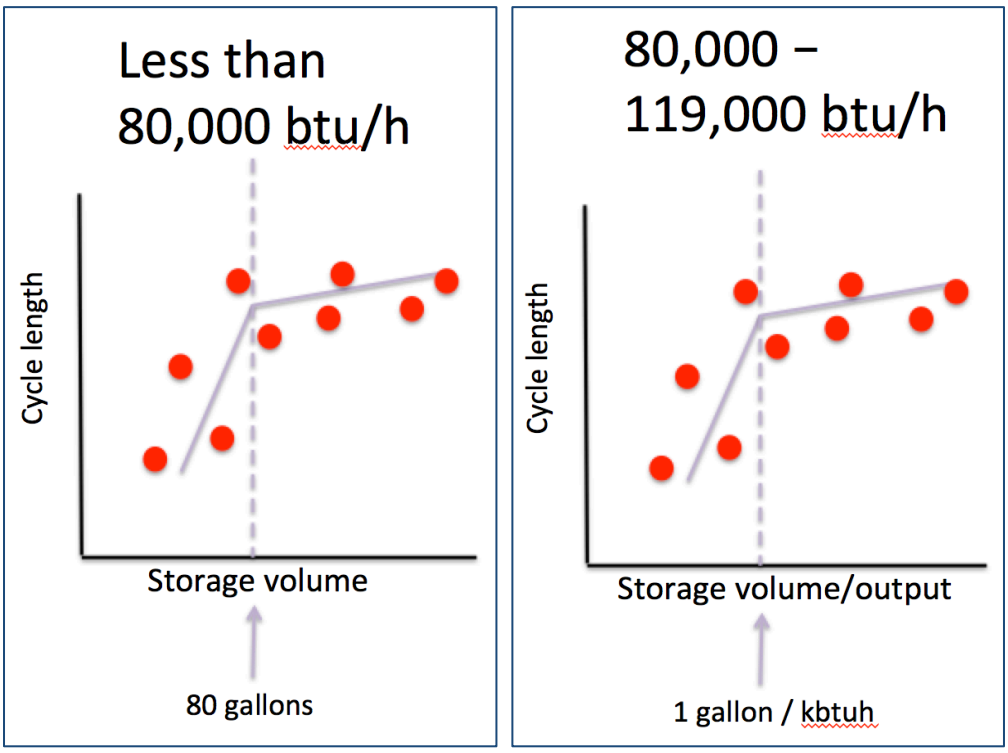
   In the Regulations, DOER chose to use **a certain volume of thermal storage** to minimize boiler cycling. 225 CMR 16.05(4)(g)4 states:

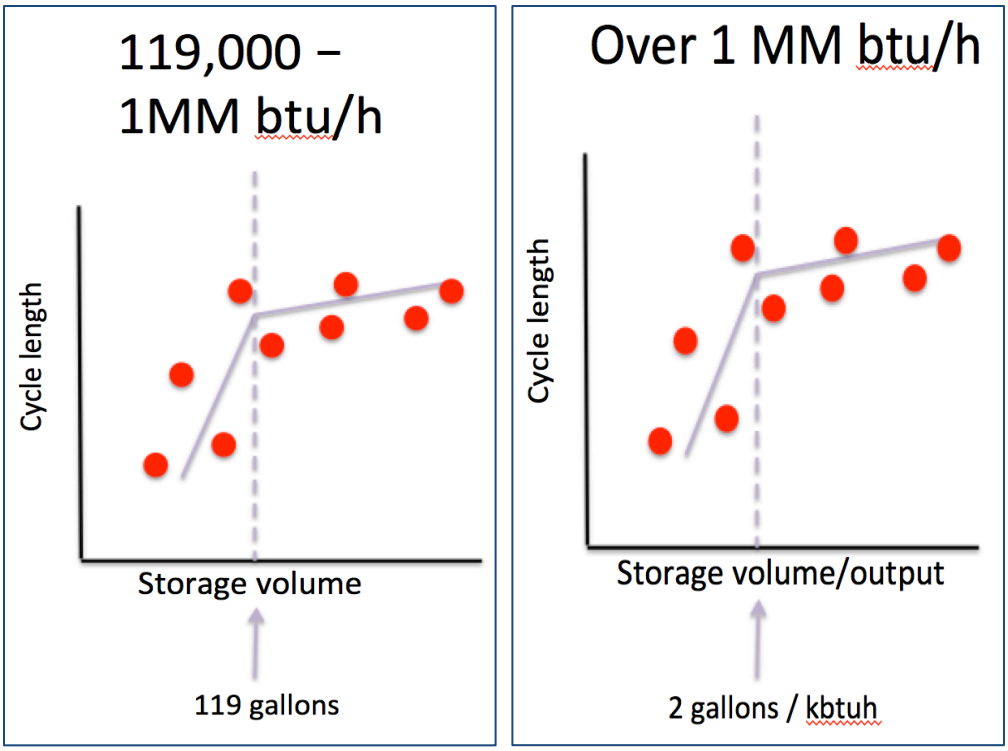
   > Generation Units shall minimize any significant deterioration of efficiency or air emissions performance due to cycling by applying **correctly sized** and insulated **thermal storage** unless the system can maintain efficiency and air emissions performance at low capacity without thermal storage. [emphasis added]

   This portion of the Regulations then lists four different sizing requirements for thermal storage, based on the nameplate capacity of the lead boiler in the

system: less than 80,000 btu/h, 80,000-119,000 btu/h, 119,000-1MM btu/h, and above 1MM btu/h.

Regardless of how DOER may have determined these sizing requirements, the requirements **implicitly posit the existence of four distinct relationships** between cycle length and thermal storage sizing, which are represented in graphs below for different outputs of their lead boiler:





[Note: These are representations only and not based on recorded data.]

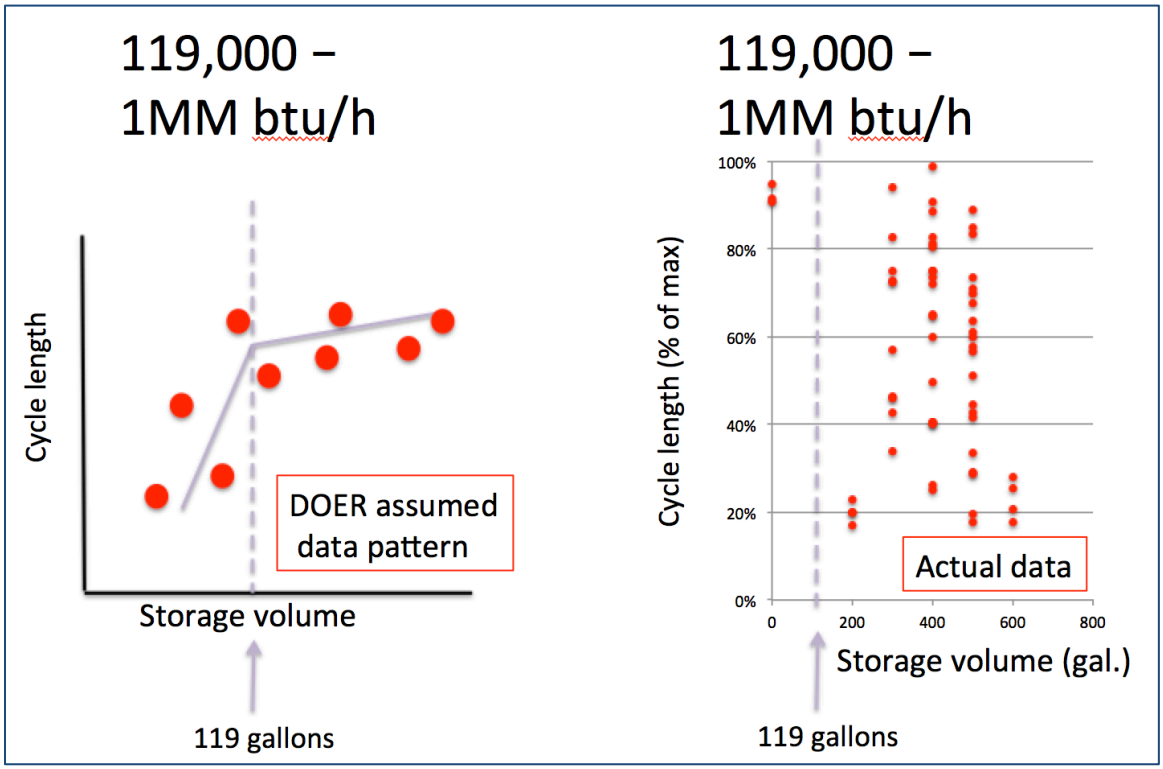
Explanation: The red dots on the graphs represent different boiler cycle lengths, graphed against thermal storage volume (or volume/output). Left of the vertical dotted lines, cycle length increases dramatically as thermal storage volume is added. After reaching the vertical dotted line, increases in cycle length for unit of thermal storage added level off, indicating that the dotted line represents the ideal thermal storage volume for each set of lead boiler output size groups.

To repeat, if DOER has correctly set thermal storage volume guidelines, these four sets of relationships (or similar relationships) between cycle length and thermal storage volume would exist (whether or not the data has actually been collected). These relationships, if they exist, would support DOER's current choice to use a certain volume of thermal storage to minimize boiler cycling.

Is any data available to test DOER's implied assumption that cycle length and thermal storage volumes are related in the manner shown by the above four graphs?

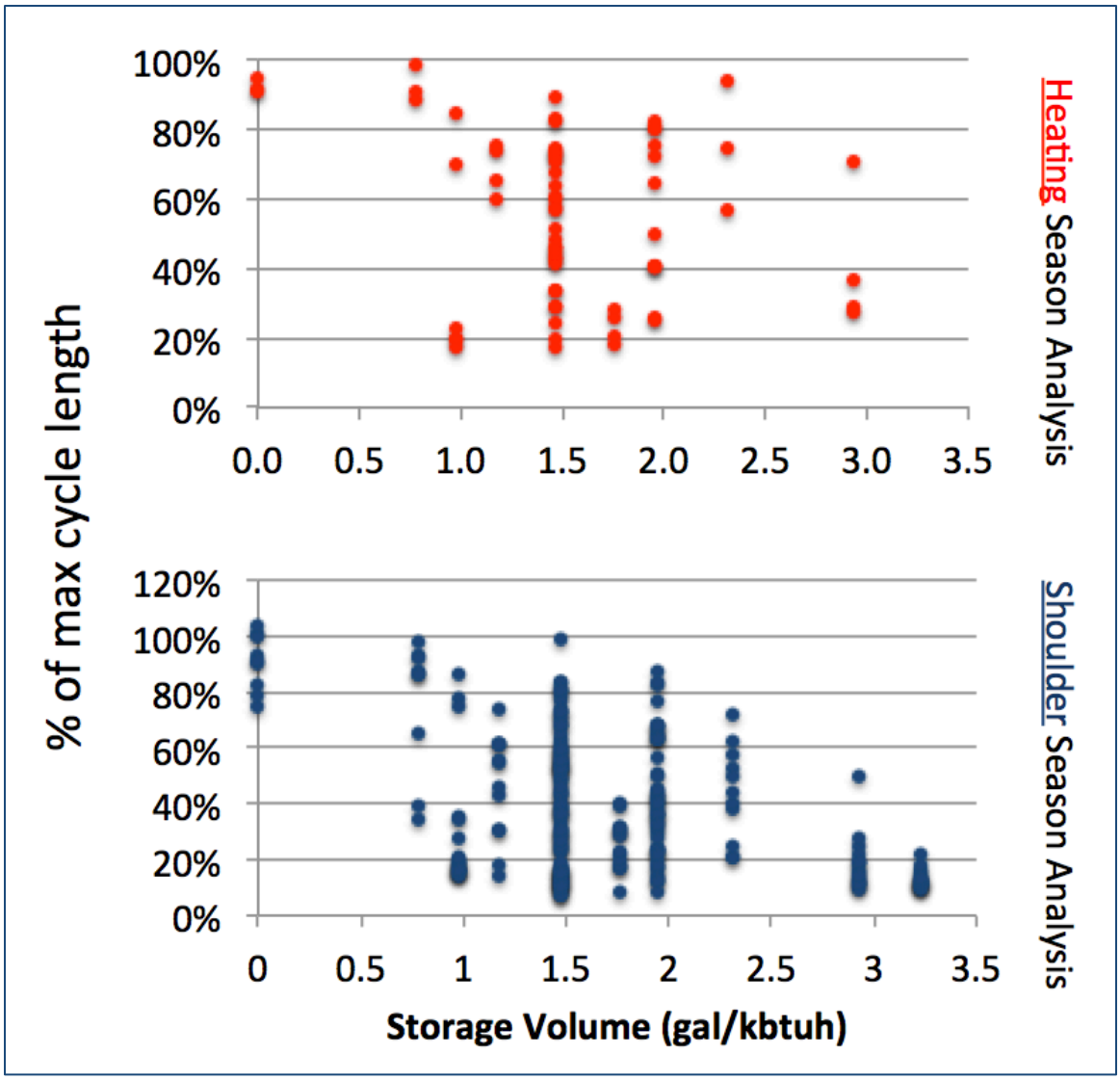
Yes. DCM Logic has monitored boiler plants for four full heating seasons. Its data can show whether such a relationship exists in the real world. The majority of this data is for boilers in the 119,000 – 1MM btu/h size range. For this size of lead boiler, the Regulations call for a thermal storage tank of 119 gallons. Below are graphs contrasting the cycle length/storage

relationship implicitly posited by the Regulations and the real world data on this relationship.



The pattern of actual data is completely different from the pattern implicitly assumed in the Regulations. Neither the 119 gallon figure **nor any other figure** fit an actual data set as being an "ideal" volume for the simple reason that **cycle length and storage volume are uncorrelated in the real world**.

(Explanation of y-axis legend on right graph, above: Cycle lengths are expressed as a percentage of maximum, to enable comparison of boilers with different maximum heating times.)



Observation: Here, cycle length and thermal storage volume/output are also not correlated, whether during the main heating season or the shoulder seasons. None of DOER's thermal storage sizing requirements (or any other possible sizing requirements) make sense for this data set.

Has anyone ever justified, using theoretical reasoning or real data, why a particular "one size fits all" thermal storage volume figure is superior to other possible figures? ("One size fits all" refers to a recommendation or requirement that all boiler plants size their thermal storage according to a guideline, regardless of boiler manufacturer or other considerations.)

Not to our knowledge. Conversations with DOER staff have shown that the storage volume requirement of 2 gal/kbtuh for lead boilers above 1MM btu/h in the Regulations and Guidelines was adopted from NYSERDA's

Renewable Heat New York program. These staff members do not know how NYSERDA determined their volume requirement. DCM Logic has corresponded with NYSERDA about this issue, but they only offered that their figure was arrived at after consultations with foreign and domestic manufacturers and experts. We have been unsuccessful in our efforts to learn whether these manufacturers and experts have data to support their views, and how conflicting advice on volumes was resolved.

Wilson Engineering Services, in a project commissioned by USFS, wrote a short information sheet on thermal storage, recommending 1 gal/kbtuh for chip systems and 0.75 gal/kbtuh for pellet boilers as a starting point for consideration.[1] We have been unable to determine whether any real world data support these figures or how it was decided that they are superior to other numbers, even as starting points.

The German government entity BAFA offers subsidies for automatic feed biomass installations with at least 30 liters/kW (2.3 gal/kbtuh) of thermal storage. (Link) We have been unable to discover how this figure was chosen.

Conclusion: The strategy of using a required volume of thermal storage has never been proved to be effective at minimizing cycling, and DCM Logic's extensive real-world data show that there is no relationship between cycle length and thermal storage volume. We can state with strong confidence that requiring a certain volume of thermal storage will fail to meet the Legislature's goal of minimizing cycling.

Recommendation: Remove the volume requirements for thermal storage in the Regulations (225 CMR 16.05(4)(g)(4)) and Guidelines (p.9, Table 4).

2. **If a certain VOLUME of thermal storage is ineffective in achieving the Legislature's goal of minimizing cycling, will STRATIFIED thermal storage succeed in accomplishing this goal?**

   Background: It is the (untested and unverified) belief of some that a stratified thermal storage tank (sized according to boiler output alone[2]) will reduce boiler cycling. Proponents of tank stratification argue that a stratified tank prolongs the time that a tank can be used for each given charge, thereby delaying the start of the next boiler cycle and decreasing boiler cycling.

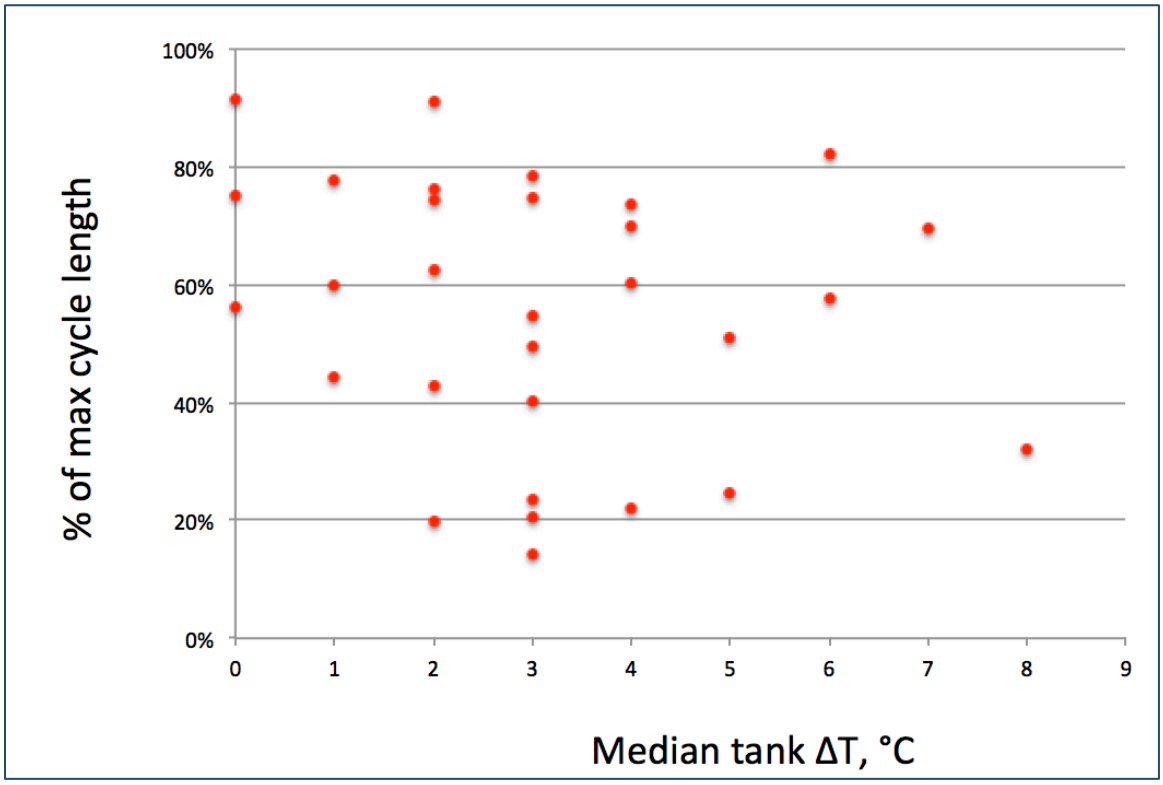
[1] Northeastern Area WERC Wood Energy Technical Assistance Team, "A Primer on the Use of Thermal Storage with Small-Medium Commercial and Institutional Biomass Hydronic Systems."

[2] A thermal storage tank designed to deliver a *substantial* amount of heat to the building for a *substantial* amount of time (hours or days) will benefit from stratification. However, this is *not* the design intent of the thermal storage (or buffer) tanks described in the Regulations and Guidelines.

The previous draft of the Guidelines prohibited horizontal storage tanks, presumably because of the above belief, as well as the fact that in a horizontal tank the distribution supply point and distribution return point are closer than in a vertical tank, making it easier to mix the tank water and disrupt stratification. This prohibition was (correctly, we think) eliminated in the current draft of the Guidelines.

Do any data exist that show a correlation between level of stratification and cycling? Not to our knowledge (for tanks designed to serve as buffer tanks, as they are in the Regulations and Guidelines).

Do any data exist that show a LACK of correlation between level of stratification and cycling? Yes. DCM Logic has examined this relationship, displayed in the following graph:



Explanation: The red dots on the graphs represent average cycle length, measured as a percentage of maximum possible cycle length, graphed against different levels of median tank stratification (top-to-bottom temperature difference). (The cycle length normalization is done to enable comparison of boilers with different maximum cycle lengths.)

What this graph tells us is that the level of stratification and cycling are **uncorrelated**. Were the two correlated, higher levels of median

stratification would coexist with higher percentages of max cycle length. That is not the case here.

Recommendation: We support DOER's removal of provisions in the previous draft of the Guidelines relating to tank stratification and recommend against including any provisions relating to stratification in the final Regulations or Guidelines (e.g., requiring stratification or certain thermal storage tank designs that are believed to promote stratification).

3. **Should the Regulations and Guidelines suggest that boilers may shut off when the heating load decreases or that they modulate when the heating load is satisfied?**

   The Regulations (225 CMR 16.05(4)(g)3) and Guidelines (p. 7, Table 3) contain the following language:

   > The system must automatically modulate to lower output and/or turn itself off when the heating load decreases or is satisfied.

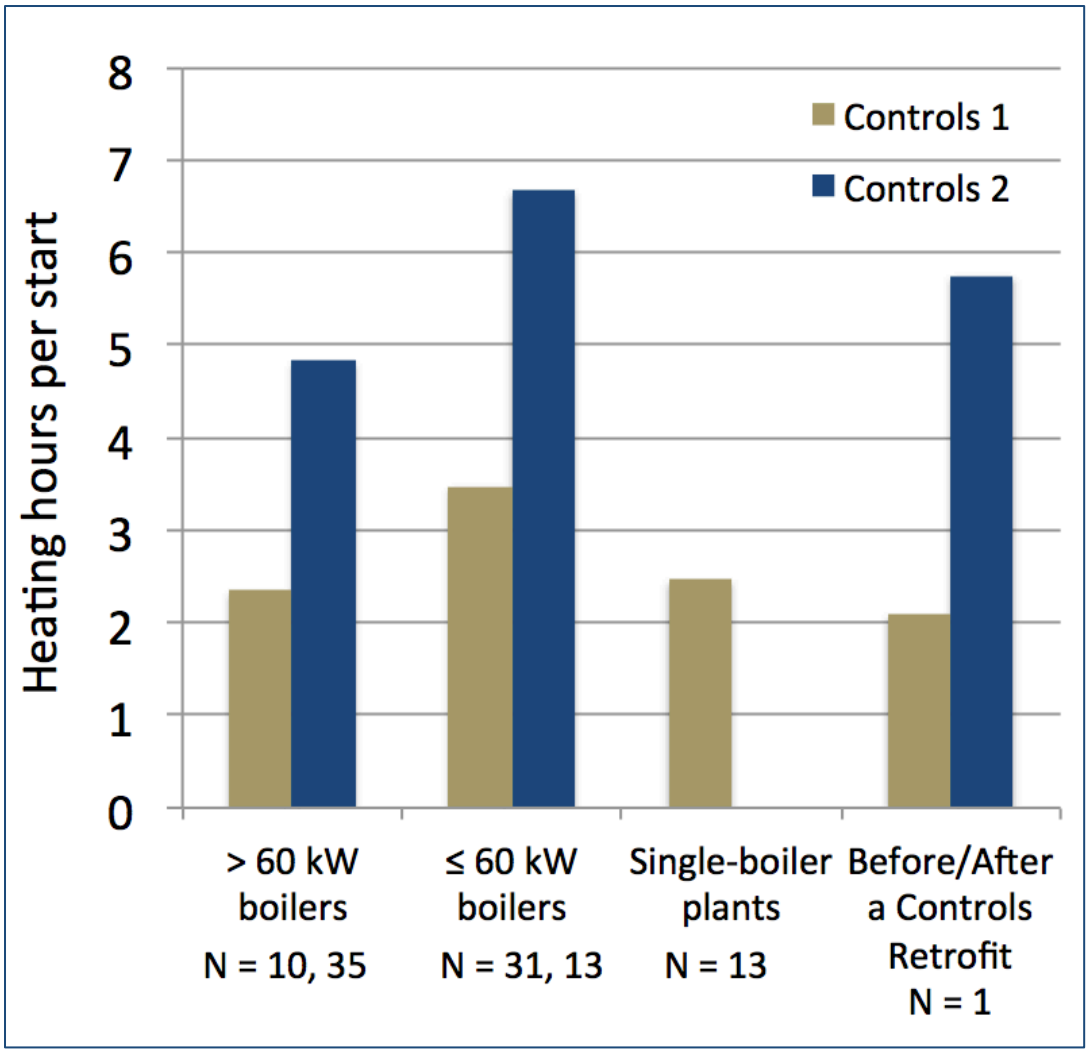
   Allowing a system to turn off when the heating load merely decreases stands in direct opposition to the plain language of the Act's requirement to reduce boiler cycling. Boilers should **modulate** to lower output when the heating load decreases, otherwise cycling will increase. Suggesting that a boiler might modulate to lower output when the heating load is satisfied is equally nonsensical. When the heating load is satisfied, the boiler should turn off.

   Recommendation: We recommend changing the language in 225 CMR 16.05(4)(g)3 and Guidelines, Table 3 to:

   > The system must automatically modulate to lower output when the heating load decreases and turn itself off when the heating load is satisfied.

4. **Does the above language about modulation accurately fit the "other means" of minimizing boiler cycling suggested by the Legislature?**

   Yes. DCM Logic has found that responsive modulation, along with responsive staging control (on/off control of boilers) **is by far the most significant contributor** to reduction in boiler cycling.



In this figure, the average heating hours per start, or average length of heating cycle, is compared for various sizes of boilers using one of two different staging and modulation controls packages. The clear message is that **controls have an overwhelming influence on boiler cycle length**.

As the Regulations and Guidelines are currently written, there is no mechanism for DOER to know whether a particular boiler can be expected to exhibit responsive modulation or whether this modulation occurs in actual operation. Given that **responsive controls are the only proven method of minimizing cycling**, we find this lack of attention to ensuring responsiveness to be a major oversight in achieving the Legislature's goals.

Recommendation: Require that Generation Units wishing to qualify must submit post-installation graphs of boiler operation exhibiting modulation behavior that successfully extends cycle lengths.

5. **Should systems with thermal storage be completely exempt from emissions and efficiency requirements when operating at any level other than maximum output?**

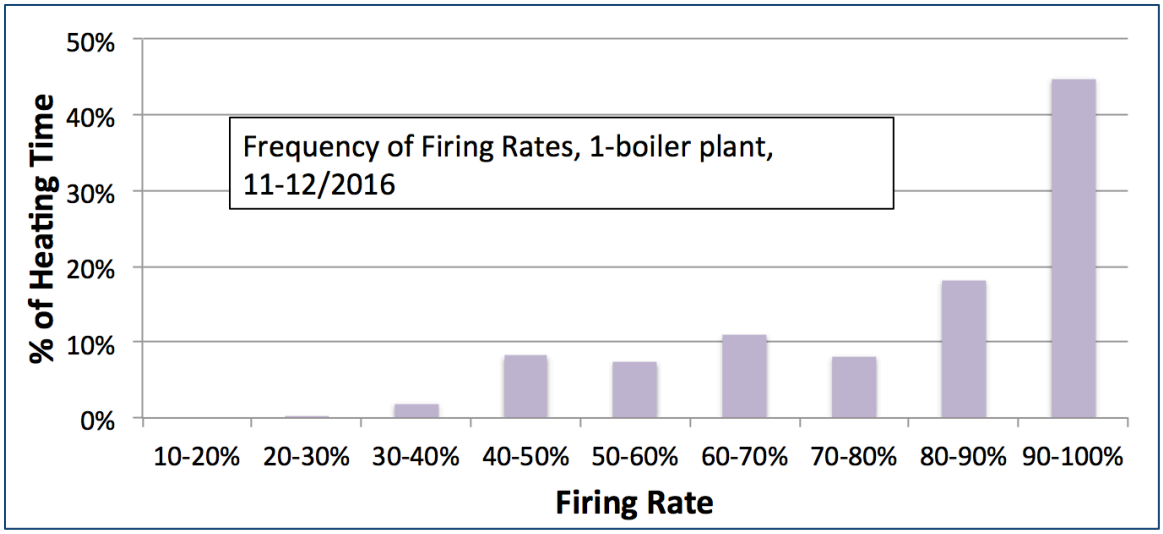
   Section 2(a)iv of the Act requires "that facilities using biomass fuel shall be low emission [and] use efficient energy conversion technologies."

   Section 2(b)i of the Act requires that the Department shall set

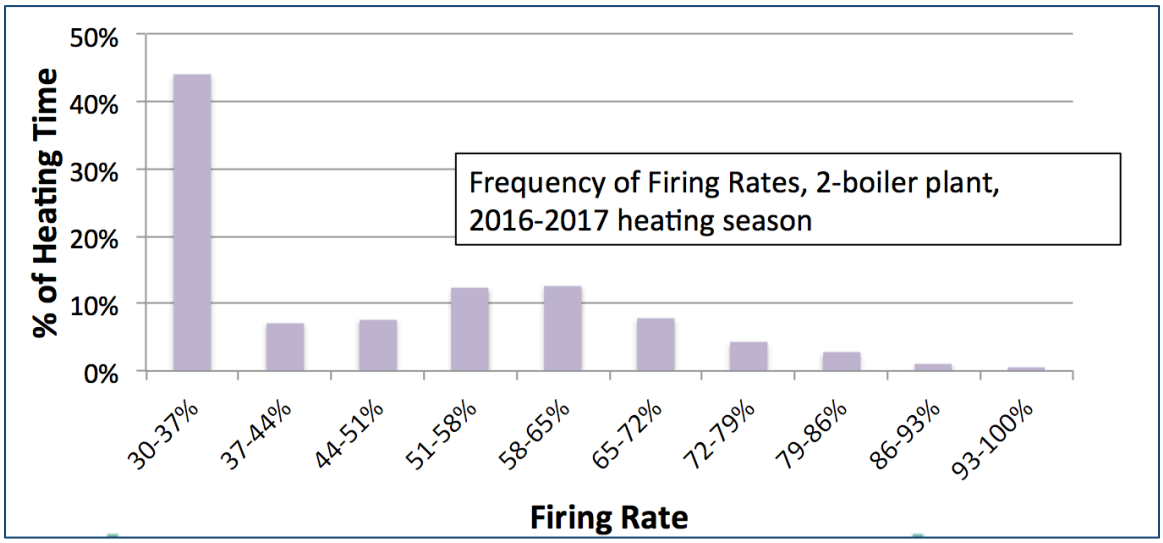
   > emission performance standards that are protective of public health, including standards for eligible biomass, biogas and liquid biofuel technologies that limit eligibility only to best-in-class commercially-feasible technologies, inclusive of energy conversion and emissions controls, with regard to reducing emissions of particulate matter sized 2.5 microns or less and carbon monoxide and other air pollutants.

   Regulations 950 CMR 16.05(4)(g)3 and Guidelines Tables 2 and 3 list efficiency and emissions requirements **at nominal output only**. Systems without thermal storage must also meet these requirements at minimum tested output level for efficiency ("minimum level" is unclear) and emissions (30% or less of nominal). As a result, the Regulations and Guidelines as written effectively give an **exemption** to systems with thermal storage from meeting **any** emissions or efficiency standards at low output operation.

   DOER's implicit assumption is that systems with thermal storage will usually operate at near-nominal output, as shown in this frequency distribution of firing rates:



while systems without thermal storage will spend a significant portion of their operating time at near-minimum output as shown in this frequency distribution of firing rates:



DOER's implicit assumption is incorrect, as the first distribution **does not have thermal storage** and the second distribution **has thermal storage**.

We do not see how the current efficiency and emissions exemption for systems with thermal storage (which may spend a large fraction of their seasonal operating time at firing rates lower than 50% of nominal output) can be considered in compliance with the Act's Section 2 requirements. As stated in the Act, biomass fuel facilities shall be "low emission [and] use efficient energy conversion technologies" and that the DOER's standards be "protective of public health," which the current exemption for boiler plants with thermal storage does not safeguard.

Recommendation: Require **all** systems, whether or not thermal storage is present, to meet emissions and efficiency requirements at minimum tested levels.

Section II: Comment on the Guidelines

1. **Can enough boilers modulate to below 20% of nominal output so as to make requirement A for omitting thermal storage a realistic option?** (Page 9, #9)

   No. Very few, if any, biomass boilers can modulate to output levels lower than 20% of full output modulation. **The effect of this provision will be to make this method for omitting thermal storage unavailable.**

   Recommendation: Change this modulation requirement to " ≤ 30% of maximum capacity," or simply require that all boilers modulate to this level, whether or not thermal storage is used.

The ideas and data used in these comments are also explained in a presentation by DCM Logic's CEO/CTO Henry Spindler, a recording of which can be found here.