<u>U.S. Heat Metering Standard: Assessment of Need and Path Forward</u>
January 10, 2013
12:30-2:00 PM EST

James Critchfield
We are going to be discussing heat metering standards for the US and have a discussion about the need and potential path forward, in particular for steam metering. Next slide.

[Next slide]
Let me start by just introducing myself. I'm James Critchfield. I work for the US Environmental Protection agency here in Washington, D.C. I also am putting on a new hat; I'm also the chair of the ASTM E44.25 subcommittee on heat metering. We'll get into a little more detail on the background of that subcommittee shortly. As you can see, we have a series of experts with us today to discuss the issue of heat metering standardization and the opportunities that exist potentially in the market on several levels and for several applications. The objective of today's webinar is to get feedback from you on today's topic. We are going to have a question and answer session, as was mentioned just moments ago. We are also going to have the opportunity for you to provide some feedback through a post-webinar survey. When you click out of the webinar at the end of today's session, a survey opportunity will pop up and you can put in some feedback regarding today's webinar for us to chew on down the road. Next slide please.

[Next slide]
So why heat metering standardization? To put it shortly, it's to assure the accurate attribution of the energy, financial, and environmental benefits generated from thermal energy sources, but this is a broader issue than just steam metering, which today's webinar was titled and focused on. There are also hydronic applications in addition to the non-hydronic applications that we are going to be covering. We are also going to touch on several efforts under way that are being considered and under development for these types of applications. Another benefit of standardization is that we are helping promote equality in markets for heat metering instrumentation. It helps manufacturers meet a single requirement for accuracy. Instead of competing on that level, they can compete on the cost and features of their products. Customers also benefit from standardization in that they are able to choose the meter that best fits their needs and their project application. It also provides them some comfort in that the products that they are selecting are actually performing as indicated or specified. Additional benefits of standardization include assisting policy makers in their ability to implement policies and support markets that are dependent on the accurate measurement or output of thermal energy sources. As we'll talk about in a second here, there are an increasing number of states that are looking at thermal energy and there is a gap in the market identified through several of these states' experiences that indicate that standardization would be a useful thing to pursue. And then lastly, to ensure fairness and confidence in the exchange of payments for energy delivered between different parties in the market. A lot of thermal energy is done through contracts and other exchanges of dollars for benefits and energy produced. Next slide.

[Next slide]
As I mentioned a second ago, lots of states are starting to look at thermal energy through their state RPS and EERS policies. One of the consequences of this sort of evolution of states recognizing thermal energy is that they are also requiring or have the requirement, as they are stewards often times of public moneys that are being used for these types of policies, to ensure

that what they're incentivizing is actually being produced. Fortunately, as states on an individual basis look at this recognition of thermal energy through these policies, you're confronted with the possibility of a balkanized environment where each state has their own unique requirement that makes it difficult for manufacturers in the market place of instrumentation, and also project developers, to understand what qualifies from state to state and situation to situation in the market. This was identified early in the process as a potential area of risk for manufacturers and other stakeholders as states look at this issue closer. There's also a trend toward supporting different types of projects, thermal projects and renewable based projects, through performance based incentives or output based incentives, as opposed to the traditional and early versions of incentive programs that were more capacity based or rebate-centric. Additionally, there's a number of thermal energy financial models that are at play in the market that involve different types of purchased contracts that are typically on an output basis. These types of contracts are dependent on the accurate attribution of the energy flows from projects. Also, there's just a more broad focus on thermal energy and its use within buildings across the nation as a lot of stakeholders who have operations are looking at reducing their carbon footprint or their energy use through their building portfolio. It's important that these individuals and stakeholders can properly assure that they are actually making a meaningful impact. Next slide please.

[Next slide]
So I would like to give a little background on the ASTM E44.25 Subcommittee on Heat Metering. In late 2011 in December, ASTM and IAPMO signed a memorandum of understanding (MOU) to establish a framework for cooperation on the development of a heat metering standard for the US. This MOU was a direct result of a proposal that a number of industry players supported and helped draft. Both ASTM and IAPMO are ANSI accredited standard development organizations here in the US and are well prepared and positioned to develop standards of this sort; these types of standards are voluntary, consensus base standards. In early 2012 last year, ASTM formed E44.25 under their E44 Committee on Solar, Geothermal, and Other Alternative Energy Sources. The E44.25 Subcommittee is focused specifically on heat metering topics and issues, and there's currently an effort underway under this subcommittee to develop a hydronic application or a heat metering standard for hydronic applications. That particular standard's development is based loosely on existing standards, primarily coming out of Europe -- prEN 1434 and also OIML R75. For those of you who aren't perhaps versed in the standards development process, a typical question is, "How long does it take to develop a standard?" Well the answer, unfortunately, is it largely depends because it is largely a function of stakeholder effort, making sure we have representation from all quarters of the marketplace and from all stakeholder perspectives. It can take anywhere from several months to a few years to develop a standard. I think if I recall correctly, the average is somewhere along the order of 18 months, but it can really depend on where you are starting from. If you are starting from a position of knowledge on the topic already, perhaps there are other standards that exist that touch on issues that are relevant and you don't have to recreate the wheel and you can customize the standard for the US market. ASTM E44.25 meets about twice a year in person and we also have virtual meetings through webinars and conference calls, much like we are having today, about every 6 weeks. So that's sort of a general time commitment if you are interested in following this process more closely. Next slide please.

[Next Slide]

Just a few words on the ANSI consensus development process. I think the big thing that I would take away from this slide is that it is supposed to be a process founded on a broad view of different public perspectives. We may be talking about heat instrumentation, and there's certainly lots of instrumentation manufacturers out there that have expertise and the real knowledge of how these types of instruments work, but it really requires a more broad perspective and series of inputs from other stakeholders in the market in order to develop what we are calling consensus. It's imperative that industries that see a need for a standard of any type provide some sort of feedback through this process so that there's balance, there's consensus, and there's openness within the process, so that the end product is reflective of the industry's needs and is suitable for the application that the standard will serve. Next slide please.

[Next Slide]
So how do you get involved in this process? The ASTM E44.25 Subcommittee could be viewed as a sandbox for several different standards activities. As I mentioned, we have one for hydronic currently underway. It's early in its development so there's plenty of opportunity for folks who deal with those types of projects and those applications to get involved. We are also considering, which is a large part of our discussion today, an expansion of the standards development activity into the steam application area and non-hydronic applications. Participation can be at any level. You can become an ASTM member and what that gets you is voting privileges on the actual ballot and standards that come out of the process. However, if you are not interested in the membership or the voting opportunities, you can still participate as just a stakeholder in the process - provide input, comment, help draft the standard - all of that is still an open opportunity for you and you do not need to be a member of ASTM. There is an online collaboration area that folks work on standards through. We post documents, have online discussions, and there's a bulletin board. If you are interested in joining the collaboration area for E44.25, please send me an email. Our next subcommittee meeting for E44.25 is scheduled for Thursday, January 17. If you are interested in joining that meeting, I recommend you contact Christine DeJong at ASTM. She's the staff manager in charge of covering the E44 subcommittees. She can provide you additional information on getting plugged in to some of our upcoming meetings. Certainly you could always email me as well, but there are some registration processes that you need to go through that are not part of the ASTM membership process that just get you plugged in to the actual meetings themselves. Next slide please.

[Next slide]
As we set up today's discussion, we have several experts with us today who are going to go over some important aspects of heat metering in general, steam metering in particular, and also some tie-ins to the hydronic side of things. We'd like you as stakeholders and interested parties to start thinking about several questions, whether you have the intention of responding and providing feedback is up to you. As I mentioned, we are going to have a Q&A Session that you can ask questions through. There will also be an opportunity in the post webinar survey and you can also just email me or contact me directly if you'd like to offer up your thoughts on the need for heat metering standards, in particular a steam metering standard. We'd love to hear about what your relationship is to the market and what your need is, as well as any thoughts you have in terms of how to construct or approach the standard itself and what concerns you have. With that I'd like to move to our first speaker of the day. Next slide.

[Next slide]

Today we have Bowen Ierna who is Vice President of ONICON incorporated, which is a Clearwater, Florida based manufacturer of flow meters and Btu energy meters, specializing in instrumentation designed for distributed thermal energy systems. Bowen has a degree in mechanical engineering from the University of Florida. He has over 20 years of experience in the instrumentation industry and is intimately involved in the design, development, and application of flow and energy measurement systems. We've asked Bowen to join us today to provide a broad overview of steam flow measurement: what's involved with it, what some of the ins and outs of measuring steam is. This will give us a basis for our additional speakers who will be talking more about some of the actual state applications and experiences that we've seen around the country. So with that Bowen, I will turn things over to you.

Bowen Ierna
Great. Thanks James. So it seems that what I'd like to accomplish today is to provide a brief, real high level overview of steam measurement, and also to provide a manufacturer's perspective for the need for standardization. As you run through the overview, I'll be pointing out different areas that would benefit from standardization performance levels. Slide please.

[Next slide]
I'd like to begin by reviewing what's happening inside a typical meter. Most steam meters are actually velocity measuring devices and we know the internal order for the meter so we can get the volumetric flow right. The actual density is required to get the mass flow rate and we'll talk about that in the next slide. Once we get the mass flow rate, the entity will tell us how much energy is actually in the steam. Slide please.

[Next slide]
So getting back to the density side, steam is a compressible fluid and so density is a function of both temperature and pressure. There are some additional measurements that need to be made along with the flow measurement. A little caveat there is that in saturated steam, temperature and pressure are dependant variables, so you can measure one and still be able to calculate density. In superheated steam, temperature and pressure are independent, so you have to measure both. Again, another little caveat here is that in saturated steam systems you do have to be a little careful because there are areas where you get unintended superheat, typically downstream of PRVs, so a single sensor measurement can result in inaccuracy in the measurement. Slide please.

[Next slide]
Now that we have established the measurements required for getting to energy from steam, we look at what you need, basically a volumetric flow meter, a pressure sensor, and temperature sensor. Those outputs are brought into a flow computer and then you are calculating mass flow and getting energy data from the steam flow. Slide please.

[Next slide]
Some of the newer technology meters are actually multi-variable meters, which have integral velocity, pressure, and temperature measurement inside and will calculate the mass flow and the energy data inside the meter head itself. Now this gives a couple of benefits. Number one, you can calibrate the meter with all these sensors intact, which results in some improvement in accuracy. Also, you can greatly reduce the overall installed cost of the metering system and that is something to be aware of as we are running through this. Slide please.

[Next slide]
I'd like to run through here some very important installation and design considerations for steam flow measurement. These are really in a prioritized ordered, although the order may change based on application. For example, if you're going into an existing system and you can't shut the steam line down, that second to last bullet all of a sudden becomes quite a bit more important and moves up the list. We'll kind of run through these individually and quickly here. Slide please.

[Next slide]
First one is reliability consideration. You have to have a meter out there that is going to work for a good, long period of time. Things to take a look at: Are there moving parts in the meter technology? If so, in a steam environment that will likely require some periodic maintenance. If you're doing waste heat recovery on the water-side for example, you have to make sure the waterfall is of sufficient quality to be able to have a turbine meter work well over a long period of time. Are there analog transducers that will drift? Can the meter meet the temperature and pressure requirements of a particular application? Are the materials of construction selected properly to prevent corrosion? All of those things are really going to factor in to the overall reliability of the measurement. Slide please.

[Next slide]
Accuracy is obviously another very important side of the measurement. The overall steam accuracy is really going to be a function of the combination of the three measurements that we saw we needed to take earlier, along with the calculation uncertainty. One of the tough things, especially for users and engineers, is that the overall number is rarely published in the manufacturer's literature. This requires the engineer and user to go out there and do some digging and some calculation in order to make sure they're getting what they need in over all accuracy. This is obviously an area where some standardization would help tremendously in being able to baseline a certain performance level. Calibration is obviously very important to the overall accuracy. There are different levels of calibration. Some meters aren't calibrated at all, some meters are calibrated electronically, and some meters are put into an actual flow loop and wet calibrated, if you will. Then having calibration certification with the meter is something that might be very important, depending on what the application is. Also, how the accuracy is expressed is very important. Slide please.

[Next slide]
This is a graph that compares a couple of very similar accuracy statements. The red set of lines is a 1% of all scale accuracy statements and the set of blue lines is the 1% of rates or reading accuracy statements. You can see up towards the right side the high flow rates that are very similar in terms of performance, but as you get into more of the typical operating range of most systems, you can see there's a very big difference in performance of the meter. This type of statement actually applies to temperature measurement and pressure measurement, so it's very important to make sure that everyone understands the different types of accuracy there, and standardization will help that tremendously. Slide please.

[Next slide]
Rangeability and turndown are other critical components of meter selection. The rangeability of the meter is just simply the range over which you can measure. We have an example here of a

meter that measures from roughly 400 to 13,000 pounds per hour and then you have some velocity numbers there as well from 10 to 300 feet per second. Turndown is nothing more than the ratio of the high and low limits of the range. So in our example you have a 30 to 1 range. Slide please.

[Next slide]
What's very important when talking about turndown is the actual settings for the turndown of the meter for the application. Continuing our example with a meter that has a 30 to 1 turndown from 10 to 300 feet per second, if the application design maximum is 80 feet per second, that meter is only going to have an 8 to 1 turndown for the application, and that might not be enough if you have widely varying steam flow rates and you want to be able to measure in partial load situations. That leads us to talking about sizing meters properly. Meters should be sized really based on flow as opposed to based on pipe size. With the same example, if we installed a 2 inch meter into that 3 inch application, you have more than doubled your effective turndown, which would really enable you to measure a much wider range of flows and be able to measure partial steam loads. Slide please.

[Next slide]
I'm going to talk a little bit about installation requirements. Most steam meters like to have developed flow entering the meter location. A straight run of pipe is what conditions the flow profile. Note that flow conditioners can be installed to minimize the amount of straight run requirements and also that the straight run requirements are dependent on what types of obstructions are upstream. Slide please.

[Next slide]
This is a table of different upstream conditions and there effects on the accuracy of metering. On the left you have the red dots, which you want to stay away from. You have the yellow dots in the middle, which aren't really as bad in terms of upstream conditions, and the goal here is to have the flow conditioned to what the meter needs to be able to perform accurately. That's going to vary depending on the actual technology of the meter and so that's just another variable that has to be considered in making selections. Slide please.

[Next slide]
Retrofit installations are something that we mentioned earlier. If you have an existing system and you want to add metering to it and you can't shut the system down, an insertion style meter might be something to consider. They can be installed in a hot tap situation without shutting down and interrupting the service. That's just another option. Slide please.

[Next slide]
Pressure valve, here's another thing that may or may not be important depending upon the actual application. This is typically more of an issue in lower pressure systems. Slide please.

[Next slide]
I'd like to close here with a brief overview of some of the more common technologies that we are seeing in steam flow measurement these days. Slide please.

[Next slide]

Vortex flow meters have been around for quite a while and they're very common in steam flow measurements. They come in different configurations. We see an insertion style here, as well an inline style. You can see a little blow up of a sensor and a block body. Slide please.

[Next slide]
Common example of vortices in nature is a typical flag behind a flag pole where we get wind hitting the flag pole and vortices are shed downstream of the flagpole. This picture on the right is actually a very interesting shot of a volcanic island in the Pacific that has alternating vortices in the clouds downstream or downwind of the volcanic island - very interesting shot there. Slide please.

[Next slide]
Bottom line here is that in a vortex style meter, the frequency of the vortices coming off the obstruction is directly proportional to the velocity of the fluid. What that drives to is a meter that is fairly robust with no moving parts, and so you get a fairly constant calibration over a long period of time. You do have to watch out, as we mentioned in some of our earlier examples on sizing, to make sure you've appropriately selected the correct size and meter. It's something that's been used quite a bit in steam flow measurement. Slide please.

[Next slide]
Another very common class of meter that's used in steam measurement is differential pressure (DP) style meters. As you can see here, there are many different types from Orifice Plates and Venturis to insertion style to different types of obstructions. As you can see here, there's a little subset of these types of meters, which are variable area meters where you are actually varying the ID of the meter based on flow rate. Those can be sensed with differential pressure or even straight gauge measurement. There are many different types of differential pressure meters out there that are very commonly used. Slide please.

[Next slide]
The differential pressure principal is basically putting an obstruction in the flow stream and measuring the pressure upstream and the pressure downstream. The flow rate is actually a function of the square of the differential pressure measurement. This is a good, robust technology that's been used for many years. It does have some good benefits and certain versions of these meters may not be as susceptible to straight run pipes and those types of things. It is fairly difficult to measure a wide range of flows because of the square relationship between differential pressures and flow rate. Slide please.

[Next slide]
Turbine flow meters are used to measure steam as well. Getting back to the reliability side, there are moving parts with this style of meter so you do need to be prepared to do some periodic maintenance on these meters and that will be a function of steam flow velocity, quality of steam, and those types of things. Where this meter actually does a good job is in situations, getting back to retrofit applications, where you can't shut the steam lines down and you want be able to hot tap an existing meter in. If you can't change the pipe size so you can't move the velocity, a lot of these applications have very low steam flow and a turbine meter might be a good selection for that type of installation. Slide please.

[Next slide]

We have a bunch of conclusions to draw here. As you can see here, steam energy measurement is a fairly complicated measurement. There are many variables that can affect the performance of the measurement. Steam is a fairly aggressive fluid so it limits the kind of fluid that can be used in the measurement. As a manufacturer, it would be very beneficial to have clearly defined performance levels, which helps with technology comparison, it helps in competitive situations, and you would like competing on an even playing field - one that's understood by the owner and the user. As the program manager or user, it can be really difficult to know that an appropriate meter has been selected and also installed correctly to give you the performance that you need in your energy measurements. Standardization of these parameters will greatly help the entire industry. At this point I'm turning it back to James and we'll go on to the next speaker. Thank you everybody.

James Critchfield
Great. Thank you Bowen. Thank you for that great presentation and great overview for us. I just want to remind everybody that if you have a question you have several options. You can type your question into the question box on the little floating window off to the right of your screen and we will be answering questions presumably in the order that they're given at the end when we have the Q&A session. You also have the opportunity to raise your hand at that time and we will try to answer questions from folks directly. If you have any follow up questions after the webinar you can also include those through the survey and we can try to get some answers for you if possible. So let's move on to our next speaker. Today we have John Ballam. He's a professional engineer with the Massachusetts Department of Energy Resources. We've asked John to provide a state example for us today of how standardization would be useful in a state situation as it relates to an energy portfolio standard. John is the Department of Energy Resources' technical resource for development and application of the Massachusetts's Alternative Energy Portfolio Standard for CHP. He also oversees the outreach and policy development for the department CHP program. He has a background of over 30 years in renewable energy efficiency and power projects and programs, which included positions as Chief Engineer with Alten Corp., the nation's first solar thermal and CHP micro utility. He also has experience as Engineering Manager for Love Construction, Inc. during the design and construction of seven and nine 280 MW concentrating solar thermal power plants, which have been online since the mid 1980's. So with that I will turn over the presentation to you John.

John Ballam
Thanks James. Hello. First of all I'd really like to express DOER's appreciation for the EPA having taken up the much needed task of sheparding through a heat metering standard's development. Thank you. In my presentation today I want to briefly cover some of the applications of steam energy Btu metering in Massachusetts that I'm either directly involved with or am aware of, and the related need and usefulness for steam energy meters standard. Next slide please.

[Next slide]
Applications for revenue grade steam Btu meters here in Massachusetts. Currently we have some state performance based incentives for steam generating CHP systems. There is also a fairly extensive commercial district steam heating existing network for the cities of Cambridge and Boston. There's also the state Leading By Example program, which has begun to monitor and report steam usage for state and municipal facilities for use in analyzing energy usage and efficiency, and in meeting energy plan goals. This is expected to be expanded. Next slide please.

[Next slide]
In the future, there's some potential that we will be adding performance based incentives for steam generated by boilers using renewable bio-fuels and waste heat recovery boilers, and I'll go over that more in the following slides. Next slide please.

[Next slide]
So in Massachusetts the specific incentives for CHP are currently the Alternative Energy Portfolio Standard, fondly know as APS, and the MassSAVE Efficiency Program. The MassSAVE Efficiency Program is an upfront CAP-X program incentive. The metering requirement comes in after the project has been installed during the monitoring and verification process. Temporary meters are installed to ensure that the performance of the system meets the projected performance. For systems that qualify for the APS, the APS meters are accepted by the utilities. Next slide please.

[Next slide]
APS-CHP, APS covers other technologies besides CHP, but CHP is the primary generator of credits at this time. So what does the APS-CHP program do? It credits CHP attributes of efficiency and net source GHG reduction per unit of useful energy generated. Qualified units generate tradable credits based on metered net fuel energy saved. And the credits then can be sold by the generators to the electricity suppliers so that they can fulfill their obligations under the portfolio standard. Next slide please.

[Next slide]
Here is a very simplified diagram of a typical CHP plant, which is generating steam and requires a steam energy meter. I think the only important thing to see there is that, it may be counterintuitive, that you typically need two meters in order to get your net steam energy. You need an output meter and you need a feedwater steam meter so you can actually come up with the net energy supplied. Next slide please.

[Next slide]
Here's an illustration of the obligation schedule as an example of how a market might be increasing in Massachusetts for steam metering. This is the obligation in MW of CHP that would be required on the yearly basis between now and 2020 to meet the portfolio standard obligation. Just be aware that other technologies could also be generating credits too, so these would then decrease in terms of CHP. Next slide please.

[Next slide]
A snapshot of the current APS-CHP shows there are approximately 65 projects that have been qualified for a total capacity of 55 MW. With an expected range of net source GHG reduction between 15% and 19% per annum. Next slide please.

[Next slide]
Steam generating systems with steam Btu meters. There are nine of them with a combined capacity of 44.7 MW. We have about 25 steam meters and that's because many of the systems have multiple meters. Range in average capacity of steam generating systems. They range from 2 to 25 MW, with an average of 5.6 MW. To give you some idea of the range of steam flows and conditions expressed in PSIGs degrees Fahrenheit and pounds per hour you can see the range there. It's fairly broad. Next slide please.

[Next slide]
System types are the standard ones you would expect: power boiler plus steam turbine generator, engine plus HRSG, combined cycle, combustion gas turbine plus HRSG plus STG. Projected annual revenues for current steam generating APS systems range between $380,000 to $2.7 million per system, so you can see that as these systems get larger, the revenue impact of the metering becomes increasingly critical. The types of steam Btu and the technologies in place: flow meters, orifice plates, and I really should have called them DP because some of them are not orifice plates they are Venturi, vortex meters, and we also have one system with a hanging bar flow meter. Typically the flow pressure and temperature signals either go into an intermediate flow computer or directly into the existing plant's distributed control system, which then is programmed to be able to compute on a real time basis and then totalize the net energy, the net steam Btu. Next slide please.

[Next slide]
To give you some idea of how the market for steam maybe increasing, we have a rather large potential addition coming along where there is an existing 255 MW merchant CHP plant, which at this time is tied into the city of Cambridge. Under construction at this time is a tie-in to the Boston district heating system, so this would be an instrumental case for the APS and would create a lot of new credits, and three new steam projects totaling 32.5 MW. At DOER we expect the continued growth in steam generating APS-CHP systems and probably, I would say, a lot of them in the 7 MW and that region, maybe 5 – 7 MW. Next slide please.

[Next slide]
Potential expansion of the APS, there is a study underway at this time to expand the APS to include systems that would have steam generated by boilers that would be fired with renewable fuels. This would be phase 1, such as biogas, biomass, and bio-fuels, and then in phase 2, at some future time, waste heat recovery steam generators. One example would be from a high temperature process, say at a foundry with a heat recovery steam generator and possibly even a turbine. Next slide please.

[Next slide]
Given this fairly broad range of applications here in Massachusetts, the DOER does have an interest in a standard for steam Btu meters. In the APS program, even though there aren't many steam systems, they are large in comparison to many of the other engine based systems. They represent a large fraction of the program's total thermal energy output and we expect this to continue to be the case. Because of this, the proper selection, reliability, and validity of steam measurements is critical to us in order meet our program management responsibilities, the basic ones of which are an accurate allocation of credits and an accurate accounting of source GHG reductions, which is one of the primary, underlying motivations for the program. Next slide please.

[Next slide]
I should say that we also have a broader, more general interest in having accurate steam measurements because we work with other agencies in trying to assemble an overall accounting of energy usage and GHG emissions from various sources in Massachusetts, many of which, such as boilers or cogeneration facilities, are metering steam. In terms of the quality of that information, a standard would be very helpful. Similar to the ANSI standard for revenue grade kWh meters, a steam Btu meter standard that can be cited by applicants and submittals would

greatly simplify the selections of the submittal and review process for both applicants and the DOER by ensuring that a known level of accuracy will be attained by any meter meeting the standard. Next slide please.

[Next slide]
That brings me to the end of my presentation and here are some names and contact information for us here that are engaged in these programs at the DOER. Thanks very much, I look forward to your questions.

James Critchfield
Great. Thank you John. Another great presentation on some of the real life applications of a heat metering standard into a state environment. We are going to shift gears a little bit here to our next speaker. We have with us today George Simons who is the director of ITRON's Consulting and Analysis division. We've asked George to join us today and provide us with a bit of a perspective on some work that ITRON has done with California, particularly with CHP systems. George is here today to share some of these perspectives on the importance of metering accuracy and the value of a heat metering standard to that end. George is responsible for providing utilities, industry, and governmental clients with expert services in the area of renewable and distributed generation, program design, implementation, evaluation, and market assessment. He has over 30 years of experience in the distributed and renewable energy arena, ranging from hands on development and trouble shooting of renewable energy projects to directing over $90 million in state of the art research and development activities. He has a bachelor's degree in chemical engineering from UC Davis. And with that George, I'll turn over the controls to you.

George Simons
Great. Thanks a lot James and good afternoon everybody. So I'm going to change the perspective that James mentioned a little bit here. Bowen did a great job in describing the nuts and bolts of steam metering and John also did a great job talking about steam metering application within a program like the APS. What I want to do today is talk a little bit about the heat metering data that's collected and used in a program setting, whether it might be hundreds of CHP systems. My intent is to really show the value of heat recovery, heat metering, and a heat metering standard. What's important to understand is that while we've talked about accuracy of metering, variability in heat recovery is going be very important in how the results are developed. Also, perceptions about what those results mean are going to be very important. So let's go to the first slide.

[Next slide]
I'm going to focus specifically on California and a program called the Self-Generation Incentive Program. It's been around since 2001. It was originally a peak demand program. It's now really a green house gas emissions reduction program. Excuse me. There's more than 530 combined heat and power projects in the Self-Gen program, representing over 240 MW of rebated capacity. That's just rebated capacity; the actual install capacity is greater. This covers conventional and renewable fuels, IC Engines, some fuel cells, gas turbines, and micro turbines. Our role in the program has been as a prime evaluator. We've been installing electricity and heat metering systems, we are responsible for collecting and compiling the performance data and then evaluating the results of the technology and program performance basis. We've installed over 100 heat metering systems within California, and you can see the projects are

distributed fairly equally over California. You can also see that IC Engines make up a vast majority of the applications within the Self-Gen program. Next slide.

[Next slide]
So let's talk a little bit about heat metering within the program. Really there are three major areas where there is value in heat recovery and measuring heat. First off, almost all projects have to meet some sort of efficiency requirement. That's true in California, as well as elsewhere in the country. In California there's a public utility code requirement that the sum of the electric generation and half of the useful recovered heat has to exceed a certain percentage of the energy entering the project on an annual basis. In addition, CHP facilities or systems have to exceed greater than 60% system efficiency. Another value of heat recovery is on obtaining green house gas emission reductions. This is a primary goal of the Self-Gen program, and useful waste heat recovery is key to obtaining net GHG emission reductions. I'll talk a little bit about that later. Lastly, as almost everybody whose attending this webinar understands, useful waste heat recovery is really critical to economic viability, not just to the project, but to a project overall and insuring a sustainable CHP industry. Within the Self-Gen program, waste heat is metered by a number of people. It's metered by hosts, by project developers, third parties, and as I mentioned by ITRON as directed by the program administrators. We don't have very many steam applications within the Self-Gen program, they are predominantly hydronic applications and there's a variety of heat metering technologies, including insertion meters and turbine meters, such as Bowen described earlier, as well as ultra sonic type flow meters. It's important to note that, as John talked about for the Massachusetts program, performance based incentives play a key role and that's true in California also. Going forward, CHP projects will receive performance based incentives and the projects are responsible for installing their own metering or obtaining the services of a performance data provider to install electric and heat metering. Next slide.

[Next slide]
You have a variety of folks who are going to be installing these systems and one of the things that we discovered early on is that sometimes there is confusion about useful waste heat recovery. This seems pretty fundamental, but I just want point out that you have a variety of folks who are installing these metering systems and if you look at a typical generation equipment's specifications sheet, you're probably going to see that the waste heat out of that generator might be referred to as useful heat. There's nothing wrong with that and there's an assumption that that heat is going to be recovered, but that may not be really what you see out in the field. Useful waste heat is really impacted by a number of factors. One of the things that is really critical to understand is that it's going to be impacted significantly by actual heat demanded by the host site, and that can change daily. It can change based on what's happening at the demand site, within the existing processes, or there can be changes in the processes at the host site. So it's important to understand that impact on what you define as useful waste heat. Next slide.

[Next slide]
I mentioned early on that one of the major benefits of heat recovery and heat metering is on efficiencies. We all know that some systems might have somewhat lower electrical efficiency. Fuel cells tend to have higher. IC engines and micro turbines might tend to have lower electrical efficiencies, which makes useful waste heat recovery critical in achieving required efficiencies. One of the things that we've noticed is that when you start talking about a fleet of CHP systems,

people tend to look at average performances, but if you are really looking at an average performance, you don't get the whole story. So if you'll notice here the slide on the right is 216.6 (b) efficiency, which is the combination of thermal and electrical. You can see that gas turbines in this particular instance had a problem achieving that 42.5 % efficiency, as well as micro turbines. You have the same sort of issue with total system efficiency. You can see that the red part on the right graph shows that useful waste heat efficiency is important in terms of overall system efficiency. And again, averages don't tell the whole story, so let's go to the next slide and let's see what might be happening underneath those system averages.

[Next slide]
You get distributions and if you look at the graph on the bottom right, we actually looked at what kind of distribution you get in terms of heat recovery rates and how does that break out? These heat recovery rates are actually kBtu per kWh generated. We see that there are some systems that have really high heat recovery rates, some with very low, and most tended to be banded around 3 kBtus per kWh generated. If you look up at the graph at the right, what we see here is this 216.6 (b) efficiency requirement. What's the distribution for micro turbines and IC engines? What we see here is the green bars represent IC engines and the red bars represent micro turbine. In this particular instance, the IC Engines tended to do fairly well and there were some that did really well up there near 62.5 %, so distribution is another way to really understand what's going on with a program or what's happening to your fleet of CHP facilities. That means that although you are collecting data for individual projects, you need to be able to put those into some overall context. We tend to use a statistical approach to determine the certainty of the results. Certainty is important because policy makers and administrators tend to look at what's going to happen to this fleet going forward, so you want to be sure of your progress relative to current goals and kind of changes you need to make with respect to the fleet. We looked at samples and we tended to look at 90% confidence and 10% precision, but that's not always the case. It's important to understand that when you talk about uncertainty, there's certainty that's inherent in the heat metering measurements, but also in the distribution, so when you start talking about these results you have to combine those two uncertainties. Next slide.

[Next slide]
So what might be some factors impacting the accuracy of useful waste heat recovery performance data? As Bowen mentioned early on, you have precision metering equipment, but the in-field precision might not always be what is specified by the manufacturer just simply because there can be different circumstances than what you'll see under the equipment spec. Placement of sensors is critical. We're talking about useful waste heat recovery and not just the waste heat offset by the generators, so you have to really make sure that you are placing your temperature and flow sensors appropriately and you take into account any sort of side streams that might impact what your consider to be useful waste heat recovery. Also, take into account that a system's configurations change over time, so what you were initially metering may not be the same if there's a change in the process. A metering system's performance can change over time, so you have to really maintain systems. The bottom right hand picture here is a new turbine meter, on the upper part of that graph or picture, versus an older turbine meter. There's nothing wrong with turbine meters -- turbine meters are a great application -- you just have to be very careful to maintain them. As Bowen mentioned earlier, water quality is critical for this. If you have systems with good water quality and maintenance over time, your turbine meter is going to last much longer. Without maintenance, what we've generally seen in California is that

the turbine meter tends to peter after about 3 years. It's also important to realize that when people are commissioning CHP facilities, they take instantaneous readings or they come back and they want to look at the useful waste heat recovery at a particular point in time. Well you might get a very different indication of how the system is performing if you're looking at an instantaneous reading versus performance over time, and that also provides you with some very important trend information. So it's important to be thinking not just about the equipment, but also the data acquisition system and how, in a project like the Self-Gen program or APS, how is that information going to be recorded and what's the time interval. Next slide.

[Next slide]
Green house gas emission reduction is of more and more interest to folks, and those emissions are influenced by a number of factors through CHP facilities. It's impacted or influenced by electricity that's displaced from the grid by the generator. There are also greenhouse emission reductions due to thermal energy displays from on-site boilers and chillers and from the waste heat recovery systems, so you have to look at the sum of those different things. Ango?? just simply refers, in this equation here, to the electricity displaced both by the generator for the CHP facility as well as the electricity from the grid. The green house gas emissions tied to the thermal end are tied to the heat that's being provided by the generator and being captured and then used in the application. Also it's important to know the demand; what's the heating and the cooling demand at the facility and what are the efficiencies of the boilers and the chillers? You have to make sure you take that into account because there can be huge variability in what happens with that demand overtime. Next slide.

[Next slide]
Here are some results where we looked at the impact of useful waste heat recovery on net greenhouse gas emissions and we saw a very strong influence of useful waste heat recovery on green house gas emissions. If you look up at the chart at the upper right hand, what we've plotted here is useful waste heat recovery in kBtu per kWh versus the year. On the right hand side of the graph you can see the net CO2 emission rates, and what we've seen is a steady decrease in CO2 emissions as in fact the useful waste heat recovery rate goes up. So the blue bars represent the heat recovery rates. In 2009, 2010, and 2011, you see a great impact on net GHG emission reductions. The bottom chart really breaks it out between heating and cooling applications within the program. What we are seeing in California is that useful waste heat recovery for thermal/ heating demand for facilities is playing a huge role in how you get to net GHG emission reductions. I want to stress that it's important to really make sure when you are putting in projects that you accurately determine what the variability will be in heat demand at the facility. Next slide.

[Next slide]
I also mentioned early on that there's an economic value to useful waste heat recovery, and this is huge because economic value is what really drives projects and CHP programs forward. Within California we've done some economic modeling, both at the program level as well as the project level, to look at the economic value. We've looked at a number of different factors and actually have some fairly extensive economic analyses that we've done. We've looked at the cost and the benefits in the Self-Gen program from different perspectives, from the owner perspective, the utility, rate payers, and society. We see that useful waste heat really provides value in different ways, immediately to the owners with avoided boiler fuel costs and this chart here provides just one snapshot from a fairly comprehensive model. We are looking at a 500 kW

IC Engine that's natural gas fueled. We're looking at the 2015 year within the model, and we actually look at these over the measured life, the entire CHP life, and on a levelized cost basis. So looking at 2015, you can see the yellow bar shows the benefit to the owner, which is quite a substantial difference between cost and benefit, on the order of 30%. This is a benefit to the owner for that particular year, so you can gain huge benefits to the owner by achieving useful waste heat recovery. We didn't run a utility case in this particular instance, so that's why you see a zero value for the utility. In terms of rate payers and society, the green bars represent the benefits from those perspectives and that's really made up of a combination of reduced gas transportation cost, as well as energy costs that are saved from the electricity displaced by electric chillers. You can see useful waste heat recovery has substantial economic value. One of the points I want to make here is that we know that useful waste heat recovery has significant benefits and that good metering is really critical to being to accurately identify, and then as John pointed out, allocate those benefits. This is critical to how you allocate them. Accuracy in your results is not just dependent on the precision or the accuracy of the metering, but you also have to take into account the variability of the cheap recovery rate within the application. You have to take both of those into account when we begin to talk about the certainty of the results. Good heat metering is critical to achieving that, but most importantly a heat metering standard is essential. Going forward in a program, a heat metering standard provides everybody with a common approach and a common terminology, and that will help to alleviate any confusion about what the results mean and shed great light on what the different components and allocation of those benefits are. So that really concludes the comments that I have about the California perspective on waste heat recovery.

James Critchfield
Great. Thank you George. Another great presentation there. I think now we are going to morph into our question and answer session. Before we get into that, I just want to remind everybody that there are two ways that you can ask questions. One would be to submit written questions through the question box on your little floating screen interface. And the other option is to raise your hand, which is also accessible through that same interface using the little tab feature that you see there in the red circle. Right now I believe we have a few questions that have been written in to our various presenters, and I will turn it over to a colleague of mine Charlie Goff to queue those questions up for each of our speakers and then we'll move into handling live questions from the floor through the raising your hand option. One last thing before Charlie takes over, I just want to remind everybody that we are looking for feedback from stakeholders on the need and path forward for the development of a steam metering standard here for the US. We had a questions slide up earlier and it would be useful in getting some thoughts on that from folks either in real time today or perhaps through the survey that will be available for folks as you click out of the webinar today. So there's an opportunity to do that and you can also email me directly. This is James Critchfield of EPA. Charlie, the floor is use.

Charlie Goff
Okay. Thanks James. The first question is for Bowen and it comes from Gary Phetteplace, I think I'm pronouncing that correctly. He asks, "What impact does steam quality have on the measurement and the reliability of the various meter types?"

Bowen Ierna
Thanks, that's a good question. Let me start by defining steam quality. It's basically the amount of moisture that's suspended in a saturated steam environment. It's usually stated as an overall

percentage. The different technologies are going to respond to that obviously differently. Typically, you want to be in the 90% or better range of contained moisture. The things that are going to affect the steam quality are going to be things like length of distribution, how well the pipes are insulated, and those types of things. So the further away you get and the worse the pipes are insulated, the more you've got chances of running into problems with steam quality. At some point the decision needs to be made to put a drier or moisture separator into the flow stream prior to the metering and to make that situation so that you've got a good metering situation.

Charlie Goff
Thank you, Bowen. The second question came in from Christopher Lindsey and this is for John. He asks, "What is the current status of CHP in the Massachusetts's APS; is it 65 MW electric or 65 MW thermal?"

John Ballam
It's 65 MW electric and our heat recovery efficiency is usually right around 50%.

Charlie Goff
Great. We have another question from Vignesh Gowrishankar and this is for George. He asks, "Is the 60% system efficiency for the SGS program based on lower heating value or higher heating value?" And George answered that it is higher heating value, but George is there anything you would like to expand on?

George Simon
Not really. I did mention that the PC 216.6 (b) is based on lower heating values, so you have to balance those two things when you are talking about the Self Gen program.

Charlie Goff
Okay. We have another question from Daniel Humphrey and I think this probably for Bowen, but possibly for George. He asks, "For low turn down steam meters, do you recommend dual transmitters or if so how do you do this with a multi-variable transmitter?"

Bowen Ierna
Good question! First we need to get back to which technology we're talking about. With a dual transmitter I'm assuming that we are talking about a differential pressure style meter. I mentioned that in a differential pressure meter the relationship between the measured variables, which are differential pressure and flow, is actually a square function, which limits the amount of turndown that you can have. With the dual transmitters set up, you can actually expand and add two different ranges butted up to each other so to speak. That's a way of getting much better turndown and low flow capability out of a differential pressure style meter. So that's one way of approaching it. On the multi-variable aspect of that I'll have to defer. We are not a manufacturer of differential pressure meters, so I don't know that level of detail. Also this gets back into the comments I made about sizing. Whatever the technology is, you definitely want to size the meter to a point where you're getting the maximum capability of the meter that you can. Some of the district steam people will actually use parallel flow meters and not just dual transmitters, but dual flow meters will have a high load and low load flow meter because on the demand side you measure from nearly zero flow all the way up to whatever the maximum load is. So measuring summertime steam usage into a building, for example, maybe

difficult to do with any single device whether it's got dual transmitters or not. In that case, you might have a one inch meter piped in parallel with a 4 inch meter and valving to go in through, and then select the meter to be used. Good question though Daniel, that's a pretty tough application.

Charlie Goff
Bowen, Daniel also asks, "Why isn't a condensate meter considered?"

Bowen Ierna
It can be. A lot of times you don't get all the condensate back because it's trapped out in different parts of the system, and so that part of it is a little tough. We have a lot of customers that measure both the steam output and the condensate, as well as the boiler feed into the boiler, in an effort to see exactly what's going on in the system. Number one, you've got a self checking instrumentation system. Then number two, you've got the capability of finding out things that are happening in your system that you may not be able to catch otherwise.

Charlie Goff
Okay great. We have a question from Charles Collins and I believe this is intended for John, but correct me if I'm wrong Charles. He asks, "For district steam systems that have been operating for many years and have at some point installed renewable energy fuel systems, when might these organizations be able to certify and sell renewable energy credits into the voluntary or compliance REC market?"

John Ballam
Well I'm not sure that I understand the question. Are we talking about systems which now back feed into the existing district steam system [inaudible]?

Charlie Goff
Charles if you'd like to raise your hand, we can unmute you so that you can have a conversation and ask your question over the phone?

[unknown]
Charles are you there?

[inaudible]

[unknown]
I don't think Charles' microphone is working correctly.

John Ballam
Let me proceed under the assumption that I'm understanding it correctly and as far as I know that's a very interesting scenario and one which will probably become more and more likely, especially in urban situations where you may have buildings with their own combined heat and power facilities that may want to, as much as with the electrical grid, they may want to input steam into the steam grid. I guess we haven't had that occur here in Massachusetts, but I would expect that we would be able to accommodate that in some way into the APS regulations. If half the steam was generated using a renewable fuel and the system was generating electricity, then also possibly into the renewable energy credit program. However, I'm sure there would be a lot

of details to work out, especially when the steam infrastructure is owned and operated by a private entity.

Charlie Goff
Charles has his hand raised, should we try one more time to see if we have answered the question appropriately?

[Unknown]
Sure. Charles are you there?

Charles Collins
Yes.

[Unkown]
Great.

Charles Collins
Can you hear me?

[Unkown]
Yes.

Charles Collins
The last speaker was getting to the point and that's that yes, if the system has been producing steam or some kind of thermal energy using a renewable fuel that qualifies in the renewable definitions of that state or region or whatever, at what point will thermal energy be recognized in the renewable energy credit markets? We have systems that are already in place and we are trying to selling these RECs. We've got active sales that can be made, but it doesn't seem that we can get these certified.

John Ballam
Is this thermal output from a combined heat and power system or from a thermal system?

Charles Collins
Thermal only system.

John Ballam
Well in Massachusetts, as I indicated in my slides, we are studying, and there is a good possibility of, adding to the existing APS program so that steam that is metered, generated from renewable fuels, and meets our qualifications will be able to earn alternative energy credits.

Charles Collins
Okay so Washington State has already done that. They have allowed for the voluntary markets, we just need to get them certified. I guess the question then becomes, what if the state has already done that, and then what's the next step? Should we wait for the steam meter assessments and this process to happen or are we ready to make sales sooner?

John Ballam

Speaking for Massachusetts, if it should happen that our regulation goes into effect before we have a US Steam meter standard, I'm sure that we would proceed as we have in the past with combined heat and power, judging on them on a case by case basis, or evaluating and approving them on a case by case basis. So you would have to work with me if you had a Massachusetts project and submit your proposed metering system. Then I would review it based on our internal requirements for accuracy, appropriateness, survivability, and reliability and then either approve it or not.

Charles Collins
So the state can certify, in essence, the methodology or the process…

John Ballam
That's what we've been doing, but we'd like to get out of that business to the extent that we can, which is one reason why we are interested in adding steam metering hopefully to the development of a US standard.

Charles Collins
I don't mean to beleaguer this point here, but in Washington State a lot of the utility companies have punted this to the Green-e Center for Resource Solutions, so that's the group that we would have to work with. We're willing to work with them, but potentially it sounds like a state certification process might be a way to go although we'd be interested in your feedback as to why you want to get out of the business and otherwise. Anyway, I don't mean to beleaguer this.

John Ballam
Sure. You have my contact information hopefully from the slide there. Will these slides be published? I ask the organizer.

James Critchfield
Yes. We can post the slides from today as well as the discussion online for future use and consumption.

John Ballam
And I think I also may have access to your email address from your registration, so I'll send you information on the Massachusetts steam metering requirements and you can take a look at that.

Charles Collins
Thank you

Charlie Goff
We have another question from Anny Huang. I believe this is for Bowen or George. She asks, "What is the range of costs associated with installing a steam meter at various levels of accuracy and sizes? What are the costs associated with maintaining, demonstrating, and verifying accuracy of the steam meter?"

Bowen Ierna
Let me answer that from a manufactures perspective first, and then I can turn it over to George or John. The cost of a steam meter in smaller sizes, let's say in the inch and a half to 3 inch size,

is typically around $3,000 or $3,500. That's the cost for the equipment only. Then as you get into larger line sizes, the cost goes up because the meter gets bigger, so a 6 inch meter for example might be in the neighborhood of about $4,000. So that gives you some idea of what the equipment costs are. From an insulation perspective, John you might have a good handle on this, you've installed quite a few steam meters.

John Ballam
I don't think I have lot of good information on steam meters, but on meters in general, on full flow meters, I think we're looking from a minimum of about $9,000 to install. Of course if you're going into a 10 inch steam line you are talking about a lot of money. I think the most important thing that we have found in Massachusetts, when you look at the payback if you're going to qualify for the APS system and earn credits and you have a reasonably efficient CHP system, is that as you get larger and larger in size the paybacks on the metering costs get smaller and smaller to where you typically are under 2 months for a payback given a 10 year lifetime. So at about 2% of your lifetime you've paid back the metering and from then on it's paying for itself. I mean its making money for you.

[Unknown]
I think we have Elizabeth Nixon on the line with her hand raised. Elizabeth are you there?

Elizabeth Nixon
Yes I'm here. I just wanted to mention that I'm from the New Hampshire Public Utilities Commission and we actually just in December issued a draft regulation for our thermal REC program and as part of our state's process we are looking for feedback, specifically on the metering as well as other requirements. Like John has mentioned, we'd rather not be in the position to look at these on a case by case basis, but until a standard is developed we'll have to do that. Through our regulations we are trying to standardize that to some degree, so any feedback would be wonderful. And you can go to our website at puc.nh.gov to read our draft regulation.

Charlie Goff
Great. James we have a question. I'm sorry. John, were you trying to say something?

Bowen Ierna
That was Bowen, I'm sorry. I was just answering Elizabeth, I'd be happy to take a look and have some suggestions.

Charlie Goff
Okay James, I think we have a question for you from Craig Tomsik. He says, "Will all types of flow meter technology be considered for the standard or just vortex, turbine, and DP?"

James Critchfield
Well generally the approach that we've been taking to date with the hydronic side, and I presume it would be similar on the non-hydronic application side, is that we are not necessarily specifying for a particular technology of metering. What we are focusing on is accuracy classifications that any type of metering configuration could apply itself towards. We are not making decisions or choices if you will on what fits into the standard. The standard is really defining the accuracy and the operational conditions that an instrument would have to meet in

order to fall within certain classifications that are set up. There are several accuracy levels that meters could apply towards, and then if you're tested towards the standard you could say you have a Class A meter or a Class C meter, or what have you.

Charlie Goff
James, we don't have any other questions right now.

James Critchfield
We are at the two o'clock hour, so maybe this is an appropriate time to tie things up. I just want to say thank you to each of our speakers and also for all the discussion from folks who attended today. Just a reminder, in the context of developing a US heat metering standards or steam meter standard, as you click out of the webinar today you will have the opportunity to provide some feedback. As you see on the screen, there are some questions to ponder as you perhaps consider providing some feedback. We would very much be interested in hearing from anybody out there on this topic. Certainly if you're interested in keeping in the loop going forward, feel free to let us know and we will let you know of opportunities to engage on the process. Again thank you everybody for your input and we'll talk to you next time around.