DNV

FINAL MEMO

CT X1931-1 Connecticut (CT) Industry Standard Practices for Boilers and Furnaces

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1 EXECUTIVE SUMMARY

This memo provides a summary of the DNV research team's findings about industry standard practices (ISP) for commercial boiler and furnace installations in Connecticut as part of a x1931-1 study. For this research, ISP is defined as the typical installation practices for lost opportunity measures, encompassing both replace-on-failure (ROF) and new construction or gut renovation projects. Retrofit or early replacement (ER) of working equipment is not included in ISP baseline recommendations, as the pre-existing conditions at the site are always the first-year baseline for ER projects. Furnace research was restricted to stand-alone systems and excludes ducted heaters and rooftop unitary (RTU) systems.

There were three phases to this study: secondary research of building codes and other literature, interviews with program administrators (PAs) and with industry subject matter experts, and triangulation of findings from these research tasks to inform final recommendations. The interviews with experts defined standard practice as typical installation characteristics outside of the incentive programs currently offered by utilities. This process will be discussed in greater detail in Section 2.

DNV found that condensing heating equipment was the most installed type for boilers. For furnaces, both condensing and non-condensing equipment was commonly specified, with site-specific circumstances providing clearer baseline equipment types.

1.1 ISP Recommendations: Boilers

DNV interviewed 10 industry professionals, including designers, installers, manufacturers, and distributors about commercial boiler ISPs. Key findings include the following:

- For buildings with hot water distribution systems, condensing hot water boilers are standard equipment. For buildings with steam distribution systems, slightly above-code steam boilers are standard practice. This finding applies equally to new construction and ROF applications.
- There is an important exception for buildings with hot water distribution systems for which the installation of a condensing boiler is not physically or financially possible due to space or venting constraints. In these cases, a non-condensing cast iron sectional boiler is the most appropriate equipment.
- Boiler efficiency ISP varies by different categories such as size and type, as does the metric used for efficiency, such as annual fuel utilization efficiency (AFUE), or thermal or combustion efficiency. When there were significant ranges within a category, researchers estimated a value based on expert interview responses and using DNV engineering judgement. Overall, efficient equipment has a high market share and, in many categories, would be standard practice in the absence of energy efficiency incentive programs.

Recommended boiler baseline efficiencies are shown in Table 1-1 below.

Table 1-1. Boiler Efficiency ISP Recommendations

Boiler Type	Current International Energy Conservation Code (IECC) 2021	Recommended
Small (<300,000 Btu/hr)	82% AFUE	92% AFUE
Medium (300,000 to 2,500,000 Btu/hr)	80% E_t	90% E_c
Large (>2,500,000 Btu/hr)	82% E_c	90% E_c
Steam	80% AFUE (<300,000 Btu/hr) 79% E_t (>300,000 Btu/hr)	82% E_c (all sizes)
Cast Iron Sectional Hot Water	82% AFUE (<300,000 Btu/hr) 80% E_t (300,000 – 2,500,000 Btu/hr) 82% E_c (>2,500,000 Btu/hr)	82% E_c (all sizes)

1.2 ISP Recommendations: Furnaces

Five industry professionals, including both designers and installers, answered the research questionnaire about commercial furnaces. Their expert opinions provided the following important insights:

- Condensing equipment and code-minimum efficient equipment were both specified, depending on the client's needs and particular applications. Both condensing and non-condensing furnaces are the ISP.
- Furnace efficiency values varied widely. Some experts specify condensing equipment in nearly all cases, but others specify standard efficiency equipment. For ROF events, the experts agreed that the presence of an existing condensing exhaust stack was an indicator that condensing equipment was standard practice for that site. Secondary research about similar market studies in Massachusetts found that, for sites with no existing condensing stack, a code efficiency furnace was typical practice. A site with unknown venting conditions or a new construction baseline should have a blended baseline, acknowledging that both condensing and non-condensing equipment are commonly specified.
- In most commercial applications, central forced air furnaces are rare, whereas boilers, direct-vent heaters, or RTU systems are common. For smaller commercial buildings with ducted furnace systems (smaller than 120,000 Btu/hr capacity), residential furnace equipment baselines should be used instead. At the time of writing, the residential baseline efficiency in CT for furnaces is 85% AFUE.

Recommended furnace baseline efficiencies as shown in Table 1-2 below.

Table 1-2. Furnace Efficiency ISP Recommendations

Equipment Type		Current (IECC 2021)	Recommended
Furnace	120,000 Btu/hr or greater	80% E_t	Unknown existing venting or new construction: 85% E_t Existing condensing stack: 90% E_t Existing non-condensing stack: 80% E_t, or code
Furnace	Less than 120,000 Btu/hr	80% E_t	Use CT Program Savings Document (PSD) ISP for residential systems, currently 85% AFUE

1.3 Ancillary Findings

In addition to the major ISP findings detailed above, the expert interview process also yielded some ancillary findings that may be useful for program designers, administrators, and implementers:

- Few (11%) of furnace projects received incentives. The experts noted that the perceived prescriptive incentive payout relative to the difficulty of filling in the project application was a major barrier.
- The majority (77%) of boiler projects received incentives. The experts noted that the program has been very effective at changing the way that they design equipment.
- For boiler projects, incentives on efficient equipment were still cited as an important decision-making factor for customers. However, several experts noted that, even if the program no longer existed, they would still specify condensing boilers and their clients would still want them.
- Venting requirements were cited by almost all experts as the biggest barrier to installing efficient equipment at a site. The second largest barrier cited was physical space for the boiler to fit into the building. One expert described a project in which a section of sidewalk needed to be excavated and an exterior subgrade wall needed to be breached to fit new, condensing boilers into the boiler room.
- Supply and return water-temperature design setpoints are tied to the distribution system in a given building, limiting a designer's ability to reduce supply water setpoints to maximize condensing operation. This suggests that there may be derating of combustion efficiency in ROF applications, relative to new construction applications; however, a value for any derating factor would be more appropriately determined in a program evaluation or separate study.

2 METHODS

The research team's methodology for conducting this ISP research was based on the Generalized ISP Protocols developed for Massachusetts in 2017.[1] This protocol provides guidelines on assigning low and high levels of rigor for determining ISP. The high-rigor protocols are typically used for high-impact measures, where significant program-wide savings are at risk. With approximately 49% of 2019 commercial and industrial (C&I) natural gas savings in Connecticut attributed to boiler and furnace measures, DNV deemed a high-rigor approach was appropriate.

The high-rigor approach to ISP for this project consisted of the following steps:

1. **Data Request** – After identifying a potential need for clarification of the commercial boiler and furnace baseline efficiency during the 2020 PSD review process, the research team requested tracking data for the chosen technologies. As boilers and furnaces were the single-largest category of natural gas saving measures in 2019, the high rigor approach was confirmed as appropriate.
   The tracking data provided to the evaluators did not include project-level tracking, so a detailed analysis of the impacts of furnace and boiler projects specifically was not possible.
2. **Secondary Research** – The research team reviewed a wide range of different reference materials, beginning with CT-specific references. This included documents referenced in the CT PSD measures to support underlying assumptions, and then expanded to include baseline reference documents, evaluation results, and TRMs from other states. The research team also reviewed the relevant sections of the CT Energy Code and federal efficiency standards. This secondary research revealed discrepancies between the ways that different jurisdictions handle baselines for boilers and furnaces and provided valuable context to inform the creation of questionnaires for the PA and expert interviews.
3. **PA Interviews** – After compiling the secondary research findings, the research team created a list of questions for interviewing PA representatives who are involved in the implementation of the incentive programs for boilers and furnaces. The PA interview process was used as an opportunity for implementation staff to have a chance to provide their own insights into how the programs handle baselines for furnace and boiler projects, and to request clarification points during the expert interview process. The evaluators requested (via the EA team contact person for each utility) that PA representatives who were actively involved in the administration of commercial furnace and boiler projects were invited to participate. A total of 11 PA representatives, including six from Eversource and five from the United Illuminating Company, were interviewed using the questionnaire in two roundtable discussions in March and April 2021. The PA interview guide is provided in Appendix 1. The results from the PA interviews and secondary research were then used to provide a framework for the expert interview questionnaire development.
4. **Expert Interviews** – One outcome of the PA interviews was an initial list of experts to reach out to for the expert interview process. DNV reached out to these experts, as well as other firms who were not mentioned by program staff and were therefore less likely to be frequent applicants to the energy efficiency incentive programs. Additionally, further contact information for boiler and furnace industry experts was solicited as a "chain recruiting" question at the end of each expert interview, a process that the evaluators have piloted successfully in similar research in Massachusetts. A total of 10 experts including designers, installers, manufacturers, and distributors completed 15 interviews, with five of the experts completing both the boiler and the furnace interview process and the other five only completing the boiler interview.

[1] *General Industry Standard Practices Protocol* prepared for and delivered to MA P73B ISP Working Group by Kevin Boyd, Jon Maxwell, and Betsy Ricker of ERS on 9/14/2017.

The full questionnaire responses for each of the boiler and furnace expert interviews are provided in Appendix 2 and 3, respectively. Readers should note that, as shown in the questionnaire, interviewees were instructed multiple times to consider industry standard practices outside of the incentive program. Because the interviewees stated that their practices within and outside of the program were largely identical, the evaluators determined that the full range of available system efficiencies should be considered. Additionally, as evidenced by the extremely high participation rate of experts in efficiency programs, it was impossible to find any trade allies with no participation in the program.

5. **Analysis** – The evaluation team compiled the expert interview answers and sought clear and consistent findings from these interviews in the context of the secondary research findings and PA interviews. The evaluation team reviewed these findings and made ISP determinations where clear trends were observable.

3 DETAILED FINDINGS: BOILERS

This section provides a more in-depth discussion of the findings for commercial boiler ISP in Connecticut.

DNV interviewed ten experts for the boiler ISP interviews. These experts and the projects that they worked on had the characteristics shown in Table 3-1.

Table 3-1. Boiler Expert Interview Characteristics

Interview ID	Interviewee Role	Equipment Qty/Year	% ER	% ROF	% NC	% Receiving Incentives
B-1	Distributor	100	n.d.			100%
B-2	Designer	12	10%	70%	20%	66%
B-3	Installer	200	10%	90%	0%	90%
B-4	Designer	20	0%	80%	20%	95%
B-5	Manufacturer	250	50%	20%	30%	75%
B-6	Designer	20	10%	85%	50%	100%
B-7	Installer	15	30%	60%	10%	90%
B-8	Distributor	75	50%	30%	20%	50%
B-9	Manufacturer rep	200	n.d.			90%
B-10	Installer	200	20%	60%	20%	50%
Boiler total		**1,092**	**29%**	**53%**	**19%**	**77%**

ER = Early Replacement; ROF = Replacement of failed or end-of-life equipment; NC = New construction or gut renovation, n.d.=no data

The expert interviewees represented nearly 1,100 boiler projects over the past two-year period. Some experts noted that their quantities were slightly lower than normal due to the impacts of COVID-19, but most experts stated that the pandemic had no impact on the number of projects that they completed. The evaluators compared the number of boiler projects to the expected population of boiler projects in Connecticut in a given year using 2012 Commercial Buildings Energy Consumption Survey (CBECS) data.[2] Assuming a 20-year effective useful life (EUL) for boilers and a building quantity scaled proportionally to the population of Connecticut relative to the New England census division, the evaluators found an expected replacement rate of approximately 1,040 boilers per year. This suggests that the experts interviewed for this project completed a significant portion of the expected number of boiler replacements in the state and are therefore a representative sample.

Most of the projects completed by the experts were ROF or end-of-life equipment. Early replacements were the second-most common and new construction projects were the least common. Perhaps the most impactful finding in Table 3-1 is that a majority (77%) of the projects that the experts participated in received incentives, and several experts noted 90% or more of their projects received incentives. Condensing equipment, which is the only boiler type eligible for incentives, is extremely common in Connecticut.

A summary of the responses and the associated ISP recommendation for each interview parameter is provided in Table 3-2. The second column provides the relevant interview question numbers from the boiler expert interview guide, which is provided in Appendix 2.

[2] https://www.eia.gov/consumption/commercial/about.php

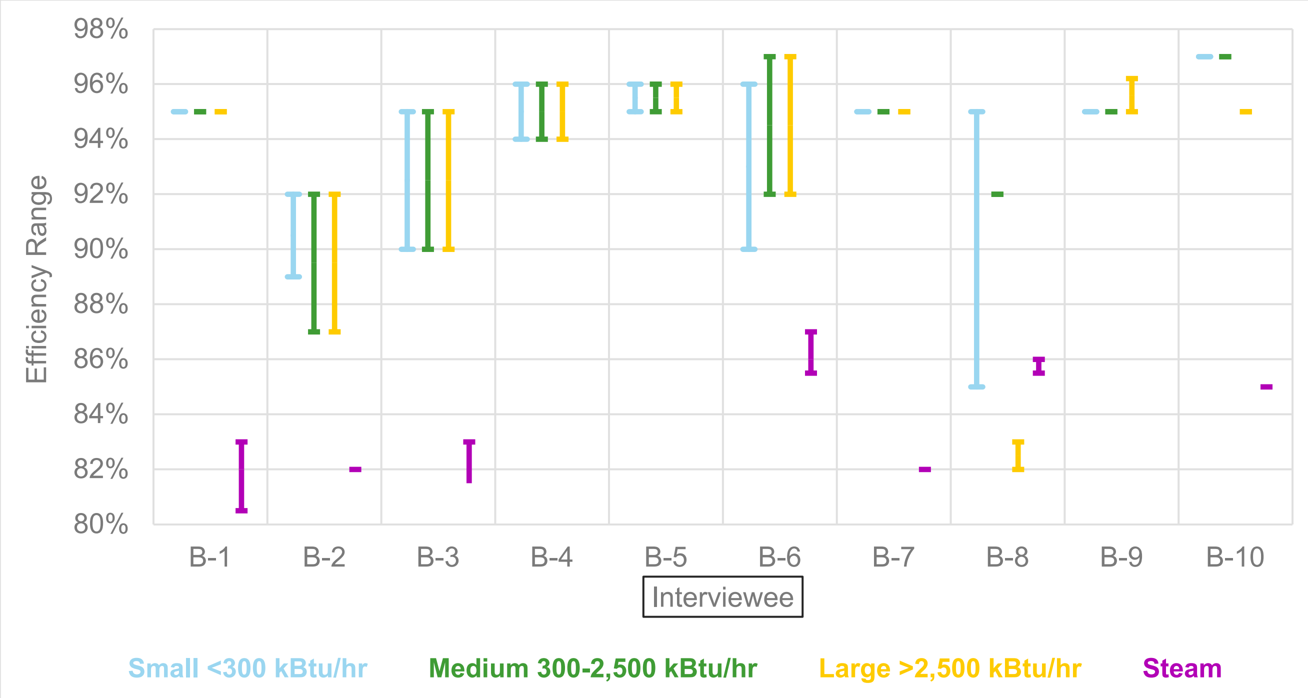
Table 3-2. Summary of Boiler Expert Interview Findings

Parameter	Relevant Questions	Summary of Expert Responses	ISP Findings and Recommendations
Boiler Type	2.1.1, 2.1.6, 2.3.3	Condensing hot water boilers are standard, except for steam boilers. Steam systems are typically replaced like-for-like.	**Hot water distribution system:** Condensing Hot Water Boiler **Steam distribution system:** Steam Boiler *Exception: for hot water systems where installing a condensing boiler is not physically possible due to space or venting constraints, a cast iron sectional boiler is the recommended baseline.*
Boiler Efficiency	2.1.2.1, 2.1.2.2. 2.1.2.3	Ranges for all sizes. Some vendors said higher efficiency on bigger systems; others noted that AFUE is different than combustion efficiency. Cast iron sectional boilers 82%-85% efficient. See Figure 3-1 for more information.	Small boilers <300,000 Btu/hr: 92% AFUE Medium boilers 300,000<n<2,500,000 Btu/hr: 90% combustion efficiency Large boilers >2,500,000 Btu/hr: 90% combustion efficiency *Exception: cast iron sectional boiler: 82% combustion efficiency*
Steam Boiler Efficiency	2.1.3	Ranges. Fewer steam boilers done now. Depends on recovery technologies. See figure 3-1 for more information.	82% combustion efficiency
Staging	2.1.4.1	Typically, multiple smaller condensing boilers are staged using integrated controllers. Use a cascade or lead/lag control. Some systems are sophisticated. Tekmar controls found where no manufacturer-specific controller is packaged.	Staging of multiple boilers is standard practice for condensing boilers.
Burner Modulation	2.1.4.2	Manufacturer controls typically include modulation. Wide ranges given for turndown.	Packaged burner modulation controls are standard practice for condensing boilers.
Supply Water Reset	2.1.4.3	This is standard on all systems.	Standard on all hot water systems.
Sensor-Based Oxygen Trim	2.1.4.4	Infrequently used. Some vendors say it is more common on larger equipment.	Standard practice to not include sensor based O2 trim.
Supply and Return Water Setpoints	2.1.5	Depends a lot on the site. Noted that lower supply temp is better, but frequently limited by the distribution system (e.g., baseboard radiation requires 180°F to work properly). Many ROF requires 180°F supply. NC maybe a little lower at 40°F delta.	Standard supply water temperature based on distribution system. Design temperature for ROF applications is often 180°F, somewhat lower for other distribution system types. 40°F delta T standard assumption between supply and return.

Parameter	Relevant Questions	Summary of Expert Responses	ISP Findings and Recommendations
Variations	2.2.1, 2.2.3, 2.2.4	Process systems often use steam. Hospitals, breweries, food manufacturing, lumber, and laboratories were specifically called out for steam use. Space heating boilers are almost always HW. Above 12,000,000 Btu, gas pressure booster often required. Radiation type changes controls set points	Space heating systems: hot water. Process: if high temperature or direct steam required, steam boiler.
Dual Fuel	2.2.2	Few new systems are dual fuel, but 20%-30% of clients have dual fuel for the sake of resiliency. Facilities with dual fuel requirements are converting to propane as a backup fuel so they can use condensing equipment.	For sites where resiliency is required (e.g., hospitals), natural gas and propane dual fuel is standard. Otherwise, natural gas only.
NC/ROF Differences	2.3.1	Wide variation in responses. Tend to match existing equipment capacity for ROF. Emergency replacements have less leeway.	No ISP difference between new construction and replace on failure.
Existing Conditions that Change Baseline	2.3.2	Existing condensing stack would always mean condensing is standard practice. On the other hand, the physical space of the boiler room may prevent condensing boilers from being installed if venting is not possible.	Existing condensing stack means a condensing boiler is always baseline.
Barriers to installing efficient equipment	2.3.3	Venting is the single biggest concern, as is spacing. If there is nowhere to vent condensing safely (e.g. due to sidewalks, or no space to run new exhaust line, or orphaned DHW system) then standard may be only option.	If physical space limitations prevent a condensing stack from being installed, a sectional cast iron boiler is the baseline.
Equipment qualifies or partially qualifies for incentive, but does not receive	3.5.1, 3.5.2, 3.5.3, 3.6, 3.7	Generally, all equipment that qualifies will receive an incentive. Few who do not, it's a paperwork issue.	Evidence of potential market transformation or free ridership
Future market changes	4.1.1, 4.1.2, 4.1.3	Expected heat pump increases. Improved controls. Condensing to continue to dominate.	Condensing equipment supported as baseline

Figure 3-1 illustrates the interviewee responses for boiler efficiencies at different capacities. Note that some interviewees provided point estimates rather than ranges. Interviewees B-4, B-5, and B-9 stated that they do so few steam boiler projects that they were unable to provide efficiency estimates.

Figure 3-1. Individual Expert Responses for Equipment Efficiencies



3.1 Discussion and Recommendations

While the expert interviews provided many valuable insights into the typical configuration for boilers of different kinds, the most impactful to the energy efficiency programs in Connecticut is that condensing boilers are typical practice for hot water boiler systems. This is a departure from the current practice in the state, which is to use the code baseline efficiency, as well as the current practice in neighbouring Massachusetts, which is to use a blended condensing and non-condensing baseline. The research team has determined that this is well justified by the expert interviews, which consistently expressed that condensing equipment was the most typical configuration for boilers. The experts further noted that they would continue to recommend condensing equipment even if there was no incentive program, and that condensing boilers were seen as extremely cost effective.

The determination of the recommended efficiency ranges for boilers of different sizes and types was made by using engineering judgement to select a representative central point among the typical efficiency ranges that the experts provided. These efficiency values, which are around 90%, are near the minimum rated efficiency for condensing boilers. This means that more efficient boilers may still be eligible for incentives from CT programs.

The experts also noted that controls equipment, such as oxygen trim controls, are still valid examples of non-standard controls that could still be considered an efficient practice. Further, as the range of design supply and return temperatures that the experts specified are potentially too high to allow for condensing operation for at least part of the year, further efficiency opportunities include replacement of distribution equipment to allow for a lower supply temperature.

Supply and return water-temperatures are not currently included in the PSD savings algorithm for commercial boilers. The ISP finding for supply and return water temperature setpoints are intended to provide further information for calculating savings in several cases:

- If a custom project involving the replacement of existing distribution systems or the implementation of more advanced water temperature controls is submitted, the ISP recommendation may be used as supporting evidence for savings calculations
- For QA/QC of future iterations of the incentive program, supply and return water-temperature information will be valuable as both installed and baseline equipment performance may be derated based on onsite conditions. As an example, as a condensing efficiency system is now the baseline, if an onsite M&V finds that supply and return water conditions on site are not conducive to condensing operation, both the baseline and the installed efficient equipment should have their efficiencies derated.
- The evaluators acknowledge that effective outdoor air temperature setback is critical for condensing boilers, as the design conditions supply temperatures that were specified in the expert interviews are too high for effective condensing operation.

The recommended increase in baseline to 90% or greater will have an impact on what equipment will be eligible for program incentives in the future. For 2021, the Energize CT minimum efficiencies to receive boiler incentives are as shown in Table 3-3.

Table 3-3. 2021 Energize CT Minimum Efficiency Requirements

Equipment Type	Equipment Minimum Efficiency for Rebate
Condensing Gas-Fired Hydronic Boilers <300,000 Btu/hr	> 92% AFUE
Condensing Gas-Fired Hydronic Boilers, 300,000 – 2,500,000 Btu/hr	>92% Thermal Efficiency
Non-Condensing Gas-fired Hydronic Boiler <300,000 Btu/hr	>85% AFUE
Non-Condensing Gas-fired Hydronic Boiler 300,000 – 2,500,000 Btu/hr	>82% Thermal Efficiency
Gas-fired Hydronic Boilers >2,500,000 Btu/hr	Custom

These efficiency values should be compared to the recommended ISP efficiencies, as shown in Table 3-4.

Table 3-4. Boiler Efficiency ISP Recommendations

Boiler Type	Current (IECC 2021)	Recommended
Small (<300,000 Btu/hr)	82% AFUE	92% AFUE
Medium (300,000 to 2,500,000 Btu/hr)	80% E_t	90% E_c
Large (>2,500,000 Btu/hr)	82% E_c	90% E_c
Steam	80% AFUE (<300,000 Btu/hr) 79% E_t (>300,000 Btu/hr)	82% E_c (all sizes)
Cast Iron Sectional Hot Water	82% AFUE (<300,000 Btu/hr) 80% E_t (300,000 – 2,500,000 Btu/hr) 82% E_c (>2,500,000 Btu/hr)	82% E_c (all sizes)

Finally, the PAs have expressed an opinion that program-qualifying equipment should never be a part of baseline recommendations. The evaluators found during the process for this ISP research that program-qualifying equipment is part of the real market even outside of incentive programs: consistently, across several lines of questioning, the expert interviewees noted that condensing equipment was the standard for boiler projects across Connecticut. The experts also stated that they would continue to specify condensing equipment even in the absence of an incentive program.

This is good news: the market for commercial boilers has evolved with the program's help over the past decades to the point that condensing equipment is the clear standard and increasing the baseline efficiency provides an opportunity for similarly increasing the efficiency standards for incentivized equipment and further transforming the market.

As long as free ridership is calculated using the ISP efficiency as its basis, there will be no double penalty to the program for having an above-code ISP baseline. A review of the current net-to-gross assumptions for boilers using the recommended ISP baseline will be necessary to ensure that free ridership is calculated correctly.

Program designers may want to elevate the minimum efficiency standard for eligible equipment to recapture some of the unit savings lost due to the ISP increase, and to reduce the free ridership that is a risk with ISP and program minimum efficiency levels are close to one another.

4 DETAILED FINDINGS: FURNACES

This section provides a more in-depth discussion of the findings for commercial furnace ISP in Connecticut.

A total of five experts were interviewed for the furnace portion of this study. The evaluators asked all experts if they would be willing to answer the furnace questions, but because few commercial central furnace projects were actually undertaken, many declined. This is likely since most forced air applications in commercial and industrial buildings are handled by direct-fired heating units or RTU systems, both of which were excluded in this study.

Table 4-1. Furnace Expert Interviews Characteristics

Interview ID	Interviewee Role	Equipment Qty/Year	% ER	% ROF	% NC	% Receiving Incentives
F-1	Designer	2	80%	0%	20%	n.d.
F-2	Installer	4	20%	50%	30%	50%
F-3	Installer	50	10%	90%	0%	10%
F-4	Designer	75	0%	75%	25%	10%
F-5	Installer	250	20%	60%	20%	n.d.
Furnace total		**381**	**15%**	**66%**	**18%**	**11%**

ER = Early Replacement; ROF = Replacement of failed or end-of-life equipment; NC = New construction or gut renovation

The number of furnace projects completed over the past two years was smaller than for boilers and with a higher proportion of replace on failure events. Notably, the furnace projects receiving incentives were a much smaller proportion of projects than was the case with the boiler projects. This suggests that a robust proportion of equipment is still in the non-condensing efficiency market.

As with boilers, the evaluators compared the quantity of furnace projects to the expected quantity of furnace projects in CT using 2012 CBECS survey data. The evaluators found that, using the same assumptions of a 20-year EUL and a proportional quantity of buildings scaled to the relative population of CT in New England, approximately 325 furnace replacement projects per year were expected. This means that, although the quantity of furnaces was low relative to the quantity of boilers that the experts worked on, the experts still installed a large proportion of the expected furnaces in CT in a given year and are therefore a representative sample.

The full questionnaire responses for each of the furnace expert interviews are provided in the Appendix 3. A summary of the responses and the associated ISP recommendation for each is provided in Table 4-2.

Table 4-2. Summary of Furnace Expert Interview Findings

Parameter	Relevant Questions	Summary of expert responses	ISP Findings and Recommendations
Furnace Type	2.1.1, 2.1.4	Experts noted that condensing equipment was frequently encountered, but code minimum efficient systems were also frequently encountered, depending on the application.	Blend of condensing and non-condensing furnaces.

Parameter	Relevant Questions	Summary of expert responses	ISP Findings and Recommendations
Furnace Efficiency	2.1.2	Expert responses varied, with several noting that variations exist.	A blended condensing/non-condensing baseline is recommended. Existing condensing stack: 90% efficiency. No existing condensing stack: 80% efficiency, or code Unknown condensing stack or New Construction: 85% efficiency. Acknowledges that there is a significant market share of condensing equipment but still a high degree of standard efficiency equipment as well.
Staging	2.1.3.1	No staging of multiple systems.	No staging of multiple systems.
Burner Modulation	2.1.3.2	Typically, some turndown on most commercial sized equipment.	Two-stage, low/high fire burner is standard practice.
Blower Motor Type	2.1.3.3	Mix of squirrel cage, permanent split capacitor (PSC), and electronically commutated (EC) motors. EC motors increasing in frequency.	EC motors are not yet standard practice but will be soon. Recommend EC motors as the ISP baseline moving forward.
Variations	2.2.1, 2.2.2, 2.2.3	Most commercial applications, RTUs and not central ducted FA furnaces are used. In some smaller applications <120,000 Btu/hr, residential systems are usually used.	<120,000 Btu/hr: use residential baseline equipment
NC/ROF Differences	2.3.1	ROF is more often an emergency replacement. Lower air velocity and discharge temp in some circumstances, like labs.	No variation by NC or ROF
Existing Conditions that Change Baseline	2.3.2, 2.3.4	Existence of a condensing stack would mean condensing equipment is standard practice.	Existing condensing stack: condensing equipment is baseline
Barriers to installing efficient equipment	2.3.3	Lack of space for a condensing stack or venting difficulties would mean non-condensing equipment is standard	Physical limitations in space for installing condensing venting: code efficiency is baseline
Equipment qualifies or partially qualifies for incentive, but does not receive	3.5.1, 3.5.2, 3.5.3, 3.6, 3.7	Some projects do qualify for incentives, but do not receive them. This is influenced by a lack of interest or time in the project owner wanting to do the paperwork, and a perceived small incentive value for prescriptive furnace systems	Some condensing equipment is sold outside the program.
Future market changes	4.1.1, 4.1.2, 4.1.3	Likely increased code efficiencies. Manufacturers will eliminate code efficiency equipment. Likely push for electrification from states and utilities.	Baseline conditions will continue to increase in efficiency over time.

4.1 Discussion and Recommendations

Partially due to the smaller number of interviewed experts, the results for furnaces are somewhat less clear-cut than for boilers. However, one clear finding is that the existence of a condensing furnace stack in an existing building is a direct indicator that only a condensing furnace would be installed in that building. Similarly, for buildings without condensing furnace stacks, a code efficiency system is the standard practice. For buildings with unknown existing venting, or for new construction projects, the evaluators recommend a blended baseline efficiency of 85%.

Table 4-3 provides the ISP recommendations for furnace efficiencies.

Table 4-3. Furnace Efficiency ISP Recommendations

Equipment type		Current (IECC 2021)	Recommended
Furnace	120,000 Btu/hr or greater	80% E_t	Unknown existing venting or new construction: 85% E_t Existing condensing stack: 90% E_t Existing non-condensing stack: 80% E_t, or code
Furnace	Less than 120,000 Btu/hr	80% E_t	Use CT PSD ISP for residential systems, currently 85% AFUE

Like boilers, the evaluators found that there is evidence of program-qualifying furnaces being installed without receiving incentives. However, for furnaces, a significant number of non-qualifying furnaces are also installed, particularly in buildings where the lowest-cost option is seen as attractive (e.g., for developer-owned new construction). Given the low number of expert responses, the low quantity of centrally ducted forced air furnaces installed in CT buildings, and the low rate of receiving incentives, the most concrete recommendation that the evaluators can provide is that the existence of a condensing exhaust stack is a clear indicator that condensing equipment will be installed again.

Assessing the presence or absence of existing condensing exhaust stacks in buildings is critical for implementing this ISP recommendation. The PAs could choose to implement data collection about the existing equipment in different ways; however, the simplest may be to have applicants check a box on the application and, potentially, submit photographic evidence of existing conditions. Program M&V would provide an opportunity to determine whether this data collection is sufficient.

The 2021 minimum program requirement to receive an incentive for a condensing gas furnace is for the AFUE or combustion efficiency to exceed 92%. This means that program minimum requirements would not have to be adjusted as a result of this ISP research but should be considered.

5 ADDITIONAL RECOMMENDATIONS

Based on the major findings detailed in the previous sections, the DNV research team has further recommendations and guidance that may be considered by program implementation staff as they adapt to the new baselines for commercial boilers and furnaces:

- Most boiler projects received incentives, and the experts noted that these incentives were effective at helping a customer confirm that a trusted partner (i.e., the utility company) considers a condensing system to be an efficient choice. This suggests that, while the recommended baseline shifts to condensing equipment, program recommendations do influence customer choices and PAs should continue to offer technical support and incentives for efficient systems and controls.
- While most furnace projects did not receive incentives, the experts interviewed noted that one major reason why was that the perceived value of the (prescriptive) furnace incentive was low relative to the time and effort cost of submitting the paperwork for an incentive. This suggests that better targeting of furnace incentives and better messaging may improve program participation rates.
- Venting requirements were cited as the single biggest barrier to installing efficient equipment both for boilers and furnaces. Additional incentive dollars to help projects with these barriers may be effective, especially since those projects have a lower recommended baseline efficiency and therefore more savings potential.
- While this project focused on CT projects, there is significant overlap in the market for all of the experts interviewed here with projects in Massachusetts and Rhode Island. Program Administrators in those locations would be justified in choosing to use the findings and recommendations of this ISP research to inform their baseline determinations.

Finally, the interview guides for the PA interview process and the expert interview process are provided as appendices at the end of this memo. These guides may be used as templates for developing questionnaires for future ISP research studies.

APPENDIX 1: PA INTERVIEW GUIDE

ISP Baseline Boiler and Furnace Research PA Interview Guide	
	Goal of PA interviews: The research team will talk with PA representatives that work closely with the commercial boiler and furnace incentive programs serving new construction and replace on failure markets. The research team anticipates speaking with up to ten PA representatives and technical assistance providers in a roundtable discussion to solicit program participation information and contact information for known market actors, as well as gather insight into the program logic and approach as it relates to boiler and furnace measures now, in the past, and as anticipated in the future. Follow-up emails may be sent to clarify answers after the discussion if needed.
0. Participant names and introductions (5 min)	
	[record participant names and positions]
	During this interview, we will be gathering information to feed into our analysis of industry standard practice, or ISP. ISP is an alternative method for defining baselines for lost opportunity projects in cases where code does not apply, or in cases where there is evidence of practices above code. As an example, research in Massachusetts in 2018 indicated that no gas-fired infrared heaters available on the market had a combustion efficiency below 82%. The program baseline for these heaters was then revised from 80% to 82%. In this discussion, we will be asking questions about your experiences with program design and your opinions about the current state of the market. We will begin by talking about furnaces, and will then move on to boilers.
1	What are the key elements taken into account for **furnace** project program design?
2	What is the standard practice for **furnace efficiency**?
3	What is the standard practice for **blower motors** in furnaces? (e.g. shaded pole, permanent split capacitor (PSC), multi-speed, EC motors)
4	What is the standard practice for **burner staging** in furnaces? (e.g. single stage, two stage, modulating)
5	Are there any differences in standard practices for **different furnace sizes**?
6	Are there any differences in standard practices for **different industries or applications**?
7	Are there any **differences in standard practices** between new construction and replace on failure for furnaces?
8	What do you consider **high efficiency practice** for lost opportunity furnace installations?
9	How have furnace standard practices **evolved over time** in CT?
10	When you talk to lost opportunity furnace customers, what is their **primary driver** for selecting efficient systems?
11	What are the key elements taken into account for **boiler** project program design?
12	What is the standard practice for **small** boiler efficiency? (<300 kBtu/hr)
13	What is the standard practice for **medium** boiler efficiency? (300-2,500 kBtu/hr)
14	What is the standard practice for **large** boiler efficiency? (2,500 kBtu/hr+)

15	What is the standard practice for **boiler burner controls**? (e.g. single stage, modulation, etc. Variation by size?)
16	What is the standard practice for **supply water temperature reset** based on outdoor air temperatures?
17	What is the standard practice for **return water design temperature at the time of installation?**
18	What is the standard practice for variable speed drives on hot water pumps?
19	How have boiler standard practices **evolved over time** in CT?
20	What do you consider **high efficiency practice** for lost opportunity boiler installations?
21	Are there any differences in standard practices for **different industries or applications**?
22	Are there any **differences in standard practices** between new construction and replace on failure for boilers?
23	What are the typical channels for boiler and furnace installations in CT? Vendor proposals? Consultants? Customers?
24	We will be interviewing manufacturers, distributors, designers, and industry experts for the furnace and boiler industry. Are there any questions that you want us to be sure to ask them?
25	Additional market actors - Who would you recommend we speak with to get more information on the furnace and boiler market in CT?
26	Is there anything else you think we need to know about boilers and furnaces in CT?

APPENDIX 2: EXPERT INTERVIEW GUIDE, BOILERS

CT EEB Industry Standard Practice Research: Boiler Vendor In-Depth Interview Guide

Date: April 2021

Purpose

Determine if current commercial space heating boiler industry standard practice (ISP) efficiency for new equipment differs from the minimum efficiency standards specified in the CT IECC 2015 code or the upcoming IECC 2021 code. Determine the ISP for boiler features and configuration. Find out if ISP varies as a function of boiler size, type, application, or other variables. Explore program influence for the purpose of ensuring ISP responses are not biased by program participation. Learn of any expected future changes in ISP. Lastly, if available, collect market share data.

Table 1: Research Objectives Mapped to Questions in This Instrument

Research Objectives	Survey Questions
ISP efficiency, controls, variation by application	2.x
Program influence	3.x
ISP Forecasting	4.x
Data	5.x

Instrument and Data Collection Information

Table 2: Overview of Data Collection Approach

Data Collection	Description
Population Description	CT-based vendors or distributors that sell boilers to end-users and HVAC system designers that specify them
Population Size/Sample Frame	Unknown, estimated 50 to 100 projects per vendor
Type of Sampling	Convenience, with targeting of larger vendors
Target Sample - Survey Completions	6-8
Instrument Type	Phone In-Depth Interview
Survey/Interview Length	45 minutes

Interviewee		Interviewer	
Interviewee Company		Interview Date	
Interviewee Phone #		Interviewee email	

Introduction

Thank you for taking the time to talk with me today. As a reminder, we're currently working on a study of industry standard practices in commercial and industrial boilers in Connecticut. We define industry standard practice as the most typical configuration for projects that do not receive energy efficiency incentives. While answering the following questions, please feel free to additionally offer perspectives on how the market might be changing based on current conditions and what you anticipate for the future.

1. Familiarity with ISP Technologies

1.1. Are you familiar with the sale and installation of commercial boilers in Connecticut? (If no, thank and end survey; if yes, circle all that apply and ask about each of these technologies in the sections that follow – may need to call another person in the firm who is more familiar to answer Qs)

1.2. How many boilers has your company sold or installed in Connecticut in the last 1-2 years? How about throughout the Northeast?

1.2.1. (COVID) – Is this different than your typical quantity in a non-COVID year?

1.3. How many were (in %):

1.3.1. Early Replacement

1.3.2. Replace-on-failures:

1.3.3. New construction:

2. Technology: Boilers

2.1. **Standard practice.** In this section, we will be discussing a few characteristics of general natural gas boiler installations. We'll talk about **typical installations** first, and then we'll talk about exceptions.

Absent any program incentives, what is the typical or standard practice for...

2.1.1. Boiler type (hot water or steam; standard or condensing)

2.1.2. Boiler **efficiency**, by size…

2.1.2.1. Small boilers (<300 kBtu/hr)

2.1.2.2. Medium boilers (300-2,500 kBtu/hr)

2.1.2.3. Large boilers (2,500 kBtu/hr)

2.1.3. Steam boiler efficiency:

2.1.4. Boiler controls:

2.1.4.1. Staging

2.1.4.2. Burner modulation

2.1.4.3. Supply water reset

2.1.4.4. Sensor-based oxygen trim control

2.1.5. Boiler set points (supply and return water temperature)

2.1.6. How do the installed boilers compare to what is required by code? (Above code, enough to satisfy code, etc.)

2.2. **Variations.**

2.2.1. Are there any **industries or applications** that systematically use or require a different configuration (type, fuel, efficiency)? What is different?

2.2.2. Are **dual fuel boilers** commonly required? In what applications?

2.2.3. Is there a **size/capacity** below or above which the typical configuration changes? How?

2.2.4. Are there instances in which the boiler controls (staging, burner modulation, supply water reset) and/or set points are systematically different than the typical practice?

2.3. **Baseline type**

2.3.1. Does the system design vary depending on whether it is replacing an existing unit, replacing a failed unit (ROF), or adding capacity to a new or existing system (NC)? If so, how?

2.3.2. Are there existing conditions (e.g. the presence of an existing condensing exhaust stack) that make condensing equipment standard practice for individual facilities?

2.3.3. Are there any barriers to installing efficient equipment in replace on failure (ROF) applications that are not present in New Construction applications?

2.3.4. Return water temperature – What temperature do you typically set (vendors) / specify (designers) for the return water temperature for condensing boilers? Does it vary between ROF and NC? How?

2.3.5. *For vendors only,* When returning to customer sites later how often do you find the return water temperature increased from its original setting, if ever? When it is adjusted, what is the typical new temperature? Does the frequency of adjustment vary between ROF and NC boilers? Do customers understand the significance of this setpoint?

3. <u>Program influence: Boilers.</u>

3.1. What percent of the Boiler projects you worked on received financial incentives or technical assistance from the Connecticut PAs (e.g. Eversource, CT Natural Gas, Southern CT Gas Co)?

3.2. What would you say is the primary driver for boiler design?

3.2.1. First cost
3.2.2. Operation and maintenance cost
3.2.3. Efficiency
3.2.4. Brand
3.2.5. Reliability
3.2.6. Physical shape
3.2.7. Features or controls
3.2.8. Other ___________________

3.3. To what extent would you say that the incentive program for boilers has impacted:
3.3.1. the market for efficient boilers?
3.3.2. (designers) how you design boiler systems?
3.3.3. (suppliers) what equipment you keep in stock?

3.4. *(if needed)* How do you think your system designs would differ if incentive programs were not available for boiler systems?

3.5. We have been discussing all projects that do not receive incentives, whether or not they qualify for them. For the sake of differentiation, are there any design commonalities for projects…
3.5.1. That qualify for incentives, but do not receive them?
3.5.2. That partially qualify for incentives?
3.5.3. That do not qualify for incentives?

3.6. What percentage of the systems that you sell or design have a program-qualifying **efficiency level** but otherwise do not qualify for incentives?

3.7. What percentage of the systems that you sell or design **qualify fully for the program but do not receive incentives**?

3.7.1. (if % of fully qualifying systems not receiving incentives is high) Why do you think so many qualifying systems are sold outside the program?

4. General Questions

4.1. **Market changes**

4.1.1. Do you expect any market changes over the next five years?

If so,

4.1.2. In what way will it change?

4.1.3. When/why do you anticipate these changes taking place?

4.2. Do the practices for boilers in CT vary by location **within the state**? If so, how?

4.3. Do the practices for boilers differ **between CT and other states** where you have worked?

5. Data Request

5.1. Can you share any historic sales data with us? We are particularly interested in how many of each boiler type and size you have sold in the last year. Details by (in order or preference) boiler type (standard HW, condensing HW, steam), boiler size, facility type, receipt of utility incentives, and manufacturer, make, and model would be particularly helpful.

5.2. Who else do you suggest we contact who is knowledgeable about the sales/installation practices for boilers in Connecticut? Can you provide me with their contact information?

6. Post call: Surveyor Impressions

6.1. Did you find this responder credible? Why or why not?

6.2. Was there anything in similar questions that are in disagreement with other comments made by the responder?

6.3. Is there a clear baseline recommendation resulting from this interview?

DNV

APPENDIX 3: EXPERT INTERVIEW GUIDE, FURNACES

CT EEB Industry Standard Practice Research: Furnace Vendor In-Depth Interview Guide

Date: April 2021

Purpose

Determine if current commercial space heating furnace industry standard practice (ISP) efficiency for new equipment differs from the minimum efficiency standards specified in the CT IECC 2015 code or the upcoming IECC 2021 code. Determine the ISP for furnace features and configuration. Find out if ISP varies as a function of furnace size, type, application, or other variables. Explore program influence for the purpose of ensuring ISP responses are not biased by program participation. Learn of any expected future changes in ISP. Lastly, if available, collect market share data.

Table 3: Research Objectives Mapped to Questions in This Instrument

Research Objectives	Survey Questions
ISP efficiency, controls, variation by application	2.x
Program influence	3.x
ISP Forecasting	4.x
Data	5.x

Instrument and Data Collection Information

Table 4: Overview of Data Collection Approach

Data Collection	Description
Population Description	CT-based vendors or distributors that sell furnaces to end-users and HVAC system designers that specify them
Population Size/Sample Frame	Unknown, estimated 50 to 100 projects per vendor annually
Type of Sampling	Convenience, with targeting of larger vendors
Target Sample - Survey Completions	4-6
Instrument Type	Phone In-Depth Interview
Survey/Interview Length	45 minutes

DNV

Interviewee		Interviewer	
Interviewee Company		Interview Date	
Interviewee Phone #		Interviewee email	

Introduction

Thank you for taking the time to talk with me today. As a reminder, we're currently working on a study of industry standard practices in commercial and industrial space heating furnaces in Connecticut. For this discussion we are only concerned with stand-alone natural gas furnaces and not those built into larger HVAC systems, such as duct furnaces or rooftop units. Additionally, while answering the following questions if you can offer perspectives on how the market might be changing based on current conditions and what you anticipate for the future.

*(**INTERVIEWER**: our focus is on typical market but gather information about disruptions to the market too. If the interviewee thinks things will be changing significantly in the future, we should capture that and flag for potential updates to the ISP study in the near future.)*

7. Familiarity with ISP Technologies

7.1. Are you familiar with the sale and installation of commercial furnaces in Connecticut? (If no, thank and end survey; if yes, circle all that apply and ask about each of these technologies in the sections that follow – may need to call another person in the firm who is more familiar to answer Qs)

7.2. About how many furnaces has your company sold or installed in Connecticut in the last one year? How about throughout the Northeast?

7.2.1. (COVID) – Is this different than your typical quantity in a non-COVID year?

7.3. How many were (in %):

7.3.1. Early replacement

7.3.2. Replace-on-failures:

7.3.3. New construction:

8. Technology: Furnaces

8.1. **Standard practice.** In this section, we will be discussing a few characteristics of general natural gas furnace installations. We'll talk about **typical installations** first, and then we'll talk about exceptions. *(**INTERVIEWER**: In some cases, it might make sense to provide ranges rather than point estimates. This is fine. Also note that we are looking for information about projects that do not receive incentives, whether or not they are partially or fully eligible for those incentives.)*

Absent any program incentives, what is the typical or standard practice for...

8.1.1. Furnace type (standard or condensing)

8.1.2. Furnace **efficiency**

8.1.3. Furnace controls

8.1.3.1. Staging

8.1.3.2. Burner modulation

8.1.3.3. Blower motor type

8.1.4. How do the installed furnaces compare to what is required by code? (Above code, enough to satisfy code, etc.)

8.2. **Variations.**

8.2.1. Are there any building types or **industries** that systematically use or require a different configuration (type, fuel, efficiency)? What is different?

8.2.2. Is there a **size/capacity** below or above which the typical configuration changes? How?

8.2.3. Are there instances in which the furnace controls (staging, burner modulation, blower motor type) and/or set points are systematically different than the typical practice?

8.2.4. Do the practices for furnaces in CT vary by location **within the state**? If so, how?

8.2.5. Do the practices for furnaces differ **between CT and other states** where you have worked?

8.3. **Baseline type** –

8.3.1. Does the system design vary depending on whether it is replacing an existing unit, replacing a failed unit (ROF), or adding capacity to a new or existing system (NC)? If so, how? *If yes, probe for whether there is a particular baseline type (retrofit, ROF, NC) that is more common for a given system design*.

8.3.2. Are there existing conditions (e.g. the presence of an existing exhaust stack) that make condensing equipment the standard practice for individual facilities?

8.3.3. Are there any barriers to installing efficient equipment in replace on failure (ROF) applications that are not present in New Construction applications? *Prompt if necessary: Having to add a condensate drain line and possibly pump? Venting?*

8.3.4. Are there any barriers to installing a condensing furnace that differ when replacing a pre-existing conventional versus a condensing furnace?

9. <u>Program influence: Furnaces</u>

9.1. What percent of the Furnace projects you worked on received financial incentives or technical assistance from the Connecticut PAs (e.g. Eversource, CT Natural Gas, Southern CT Gas Co.)?

9.2. What would you say is the primary driver for furnace design?

a. First cost
b. Operation and maintenance cost
c. Efficiency
d. Brand
e. Reliability
f. Physical shape
g. Features or controls
h. Availability of incentives
i. Other ___________________

9.3. To what extent do you think utility incentive programs for furnaces have impacted:

9.3.1. The market for efficient furnaces?
9.3.2. (designers) the way you design systems?
9.3.3. (suppliers) the equipment that you keep in stock?

9.4. *(if needed)* Do you think your system designs would differ if incentive programs were not available for furnace systems? *If yes,* How?

9.5. We have been discussing all projects that do not receive incentives, whether or not they qualify for them. For the sake of differentiation, are there any design commonalities for projects…

9.5.1. That qualify for incentives, but do not receive them?
9.5.2. That partially qualify for incentives?
9.5.3. That do not qualify for incentives?

9.6. What percentage of the systems that you sell or design have a program-qualifying **efficiency level** but otherwise do not qualify for incentives?

9.7. What percentage of the systems that you sell or design **qualify fully for the program but do not receive incentives**?

9.7.1. (if % of fully qualifying systems not receiving incentives is high) Why do you think so many qualifying systems are sold outside the program?

10. <u>General Questions</u>

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<u>These next few questions are about your perception of the overall furnace market, and not just that of your business.</u>

10.1. **Market changes**

10.1.1. Do you expect any market changes over the next five years?

<u>If so,</u>

10.1.2. In what way will it change?

10.1.3. When do you anticipate these changes taking place?

10.1.4. Why?

11. <u>Data Request</u>

11.1. Can you share any historic sales data with us? We are particularly interested in how many of each furnace type, size, and efficiency you have sold in the last year. Details by (in order or preference) furnace type (standard, condensing), furnace size, facility type, receipt of utility incentives, and manufacturer, make, and model would be particularly helpful.

11.2. Who else do you suggest we contact who is knowledgeable about the sales/installation practices for furnaces in Connecticut? Can you provide me with their contact information?

12. <u>Post call: Surveyor Impressions</u>

12.1. Did you find this responder credible? Why or why not?

12.2. Was there anything in similar questions that are in disagreement with other comments made by the responder?

12.3. Is there a clear baseline recommendation or recommendation resulting from this interview?

APPENDIX 4: ADDITIONAL REFERENCES (ATTACHMENTS)

Literature review notes

Boiler_Furnace_Research_Summary.xlsx

Expert Interviews- full text

Expert Interviews Full Text.xlsx

About DNV

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.