Drain Water Heat Recovery (DWHR) Technology in Canada: review of the physics, codes/standards, and commercially available products

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Drain Water Heat Recovery (DWHR) Technology in Canada

Review of the physics, codes/standards, and commercially available products

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National Research Council Canada | Conseil national de recherches Canada

Canada

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Executive Summary

Drain Water Heat Recovery (DWHR) units are heat exchangers designed for recovering thermal energy from warm water that travels down shower drains. There are numerous challenges this technology faces for broader application in Canada, which span from misleading terminology to inapplicable building codes and rated conditions.

Semantically, the phrase drain water heat recovery is misleading when referring to these heat exchangers, as their operation is not applicable to black water in drains, nor is it applicable to fixtures that do not have concurrent water draw and drainage (e.g. clothes or dishwashers).

In terms of building codes across different Canadian jurisdictions, none have incorporated the latest CSA (Canadian Standards Association) standard covering the performance of DWHR heat exchangers, namely CSA B55.1-20, which was published in 2020. This is a significant oversight, as CSA B55.1-20 incorporates near-horizontal DWHR heat exchangers into the rating procedure; prior to this (i.e. CSA B55.1-15), horizontal designs could not be rated nor certified in Canada. The consequences of outdated codes in this case are as follows:

- Local codes such as Ontario's SB-12, refer to an outdated version of the CSA standard, which only allows for installation of vertical DWHR heat exchangers.
- Local codes such as Ontario's SB-12, include minimum efficiency requirements for DWHR heat exchangers; however, these minimums are based on vertical units, and a market-sweep of commercially available products revealed that out of over 50 products, only 3 are of horizontal design while meeting the minimum requirements.

In terms of realistic installations for DWHR heat exchangers, neither local building codes nor CSA B55.1 account for plumbing configurations where heat exchangers get installed. The thermal performance for a DWHR heat exchanger is a strong function of flow rates passing through it, and these flow rates are influenced by the plumbing configuration in the dwelling. The rated effectiveness value that is determined through the CSA standard is only applicable to one particular plumbing configuration, while neglecting all other possibilities.

As summarized, DWHR technology is facing challenges on multiple fronts, which have collectively barred optimal utilization of the technology in Canada. Building codes often promote the adoption of efficient technologies by granting *points*; however, it is important to tackle the identified issues beforehand to ensure these points are awarded appropriately. Failure to address these issues could lead to inconsistencies and potential misuse of the point system.

1. Introduction

This report has been prepared in response to the growing demand for energy-saving measures, and the lack of information regarding a particular class of heat exchangers referred to as Drain Water Heat Recovery (DWHR) units. The main objectives for this report are to identify the inconsistencies and potential issues revolving DWHR technology along with their associated codes and standards in Canada.

It is perhaps best to start with a textbook definition. A heat exchanger is a device used to facilitate the transfer of thermal energy between two or more media (fluid or solid) [1]. There are a multitude of devices that fit the definition of heat exchangers, and DWHR units are one of them. Figure 1 shows three different DWHR products from different manufacturers. DWHR units are designed for recovering thermal energy from water going down shower drains. The certification for DWHR heat exchanger is done through Canadian Standards Association (CSA) standards B55.1 and B55.2 [2, 3, 4, 5, 6, 7], which will be elaborated on later in the report.

Figure 1: Different designs for vertical DWHR heat exchangers.

Prior to discussing codes and regulations, it is important to address one of the misleading aspects of the technology that stems from the name given to these particular heat exchangers. The phrase *Drain Water* implies that DWHR units would work for any water that goes down any drain in a residential dwelling. This is false. As was mentioned previously, these heat exchangers are designed primarily for recovering energy from water traversing down the shower drains. The implication here is that cold water is drawn through the heat exchanger while warm water from the shower is going down the shower drain. In other words, water is to be drawn and drained simultaneously. For example, if the occupant were to take a bath instead of a shower, the potential energy recovery is not realized because the water draw occurs long before the bathtub is drained. On another note, despite having the word *Drain* in their name, DWHR heat exchangers are not designed for use with black water[1]. In summary, despite being referred to as drain water heat recovery units, this particular technology is really only intended to work for showers, faucets, and other similar fixtures where cold water draw and warm water drainage happen concurrently.

DWHR heat exchangers are divided into two categories based on their intended installation: Vertical and Near-Horizontal. In this context, Vertical refers to units that are meant to be installed vertically, replacing a vertical drain stack. The units shown in Figure 1 are designed for vertical installation, and Figure 2 depicts the installation of a DWHR unit at one of National Research Council's test houses located in Ottawa [8]. The vertical units rely on the formation of a falling film of water inside the drainpipe, similar to what is shown in Figure 3. Water moves down the drain while sticking to the inner surface of the drainpipe; this forms an annular ring of water referred to as a falling-film. Vertical DWHR heat exchangers are also sometimes referred to as falling-film DWHR heat exchangers.

The second type of DWHR heat exchangers includes designs that are meant for near-horizontal installations. Near-horizontal variations of DWHR heat exchangers are meant to replace horizontal drain pipes, and no longer rely on a falling film. In terms of performance, vertical units are much more effective than near-horizontal ones, which is predominantly due to the high convective heat transfer coefficients associated with falling films. Hence, the majority of units available on the market are of vertical design. See Appendix A for a consolidated list of commercially available products in North America and Europe.

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1 Per the EPA South Australia, black water is any waste from toilets or urinals, and greywater is any "wastewater that has been used for washing, laundering, bathing or showering" [18].

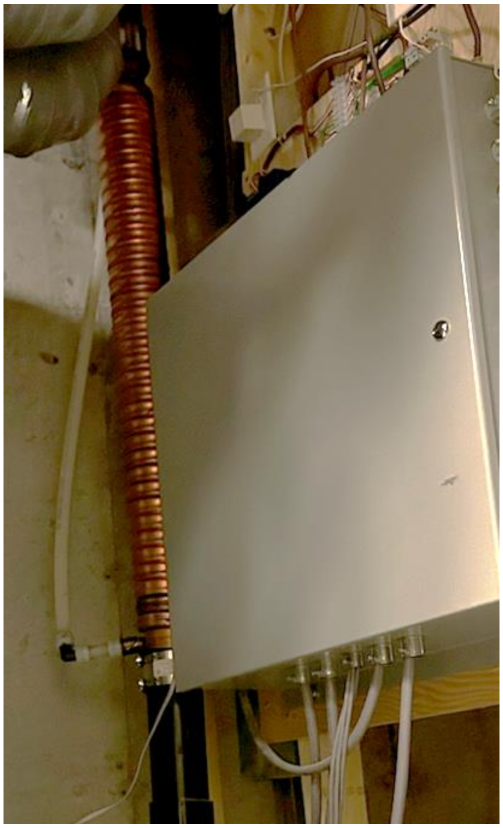

Figure 2: Example of a vertical DWHR heat exchanger in the basement of a residential dwelling [8].

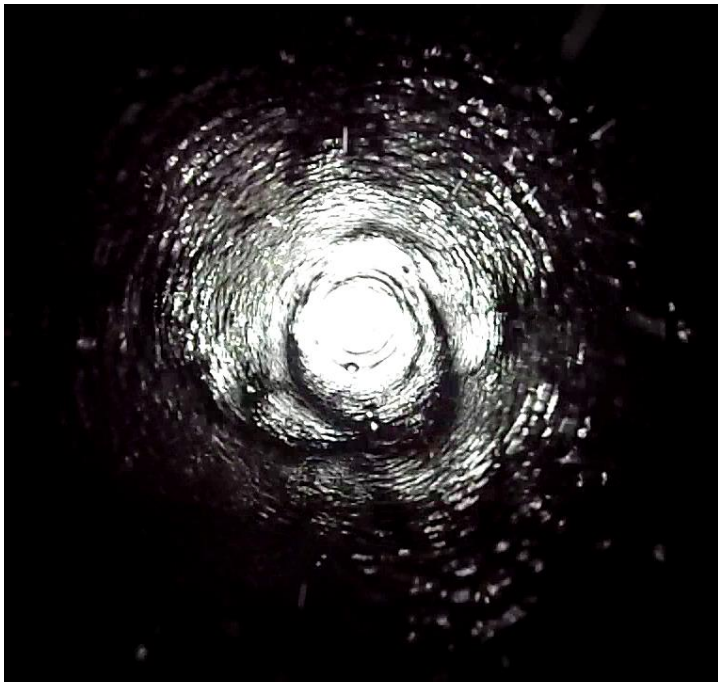

Figure 3: A photograph of the falling film of water that forms inside vertical DWHR heat exchangers during typical operation.

2. Rating Procedure and Performance Metric

As was mentioned previously, DWHR heat exchangers are rated according to CSA standards B55.1 and B55.2 [4, 7]. Standard B55.1 describes the process to assess thermal performance and pressure drop for each unit at prescribed conditions, whereas standard B55.2 dictates the requirements for safety and durability of the heat exchangers. The scope of this report is limited to the contents of standard B55.1, and more specifically, the thermal performance metrics during operation. Prior to identifying the issues with the codes and standards, it is prudent to introduce and discuss the heat transfer metrics used for measuring thermal performance in the standards.

The metric used for characterizing the thermal performance of DWHR heat exchangers is referred to as heat exchanger effectiveness, ε. This metric is adopted from a well-known procedure called ε-NTU [9], which is one of the predominant methods for characterizing many different classes of heat exchangers. Heat exchanger effectiveness is a nondimensional metric ranging between 0 and 1, which quantifies the ratio of heat transfer that actually occurs at a given operating condition, to the maximum heat transfer that could hypothetically occur at the same operating condition. See eq. 1 and 2 [9]. Note that effectiveness is measured during steady-state operation of heat exchangers, and this report does not cover nor account for transient operation of DWHR heat exchangers.

$$\varepsilon = \frac{actual\ heat\ transfer\ rate}{maximum\ heat\ transfer\ rate} \tag{1}$$

$$\varepsilon = \frac{\dot{q}_{actual}}{\dot{q}_{maximum}} = \frac{\dot{C}_{cold} \cdot \left(T_{cold,out} - T_{cold,in}\right)}{\dot{C}_{min} \cdot \left(T_{hot,in} - T_{cold,in}\right)} = \frac{\dot{C}_{hot} \cdot \left(T_{hot,in} - T_{hot,out}\right)}{\dot{C}_{min} \cdot \left(T_{hot,in} - T_{cold,in}\right)} \tag{2}$$

where $\dot{q}$ represents the heat transfer rate [W], $\dot{C}$ represents the heat capacity rate [J/(s·K)], and T represents temperature [K]. The subscripts *cold* and *hot* refer to the sides of the heat exchanger, *in* and *out* refer to inlet and outlet, and *min* is short for minimum. In this context, $\dot{C}_{min}$ is the smaller value between $\dot{C}_{cold}$ and $\dot{C}_{hot}$. The heat capacity rate can be written in terms of mass and volumetric flowrates as shown in eq. 3.

$$\dot{C} = \dot{m} \cdot Cp = \rho \cdot \dot{V} \cdot Cp \tag{3}$$

where $\dot{m}$ is the mass flowrate [kg/s], $\dot{V}$ is the volumetric flowrate [m^3/s], Cp is the specific heat of the fluid [J/(kg·K)], and ρ [kg/m^3] represents density for the fluid. Note that the above expression for $\dot{C}$ implicitly assumes that the heat transfer fluid is incompressible, and that there is a linear relationship between changes in enthalpy and temperature.

The test procedure prescribed by CSA B55.1 uses a simplified version of eq. 2 for rating DWHR units. In their approach, the heat exchangers are only tested with water as the fluid media, and the flowrates are kept equal on both sides of the heat exchanger for rating purposes. In other words, the heat capacity rates on both sides are equal during the rating process (i.e. $\dot{C}_{cold} = \dot{C}_{hot} = \dot{C}_{min} = \dot{C}_{max}$), which simplifies eq. 2 to only be a function of temperatures as per eq. 4. Each DWHR heat exchanger is tested at prescribed inlet temperatures, at a total of six flow rates (i.e., 5.5, 7, 9, 10, 12 and 14 L/min); the effectiveness is then calculated for each of the six operating conditions using eq. 4.

$$\varepsilon = \frac{\left(T_{cold,out} - T_{cold,in}\right)}{\left(T_{hot,in} - T_{cold,in}\right)} \tag{4}$$

Next, a curve fit in the form of eq. 5 is applied to the six experimentally measured data points to generate an equation, which is then used to estimate the heat exchanger's effectiveness at a volumetric flowrate of 9.5 L/min [4]. Here, a [min/L] and b [unitless] are regression constants found using the experimental data produced during CSA testing. Figure 4 shows characteristic curves for a given DWHR heat exchanger as a function of flowrate in balanced conditions. The range of flowrates tested as part of CSA B55.1 are denoted as *'CSA Range'* on the figure, and the red star corresponds to the effectiveness at a balanced flowrate of 9.5 L/min. This estimated performance point is the metric that gets printed on the sales label for each DWHR heat exchanger, along with the corresponding (estimated) pressure loss at the same flow rate. See Figure 5.

$$\varepsilon = \frac{1}{a \cdot \dot{V} + b} \tag{5}$$

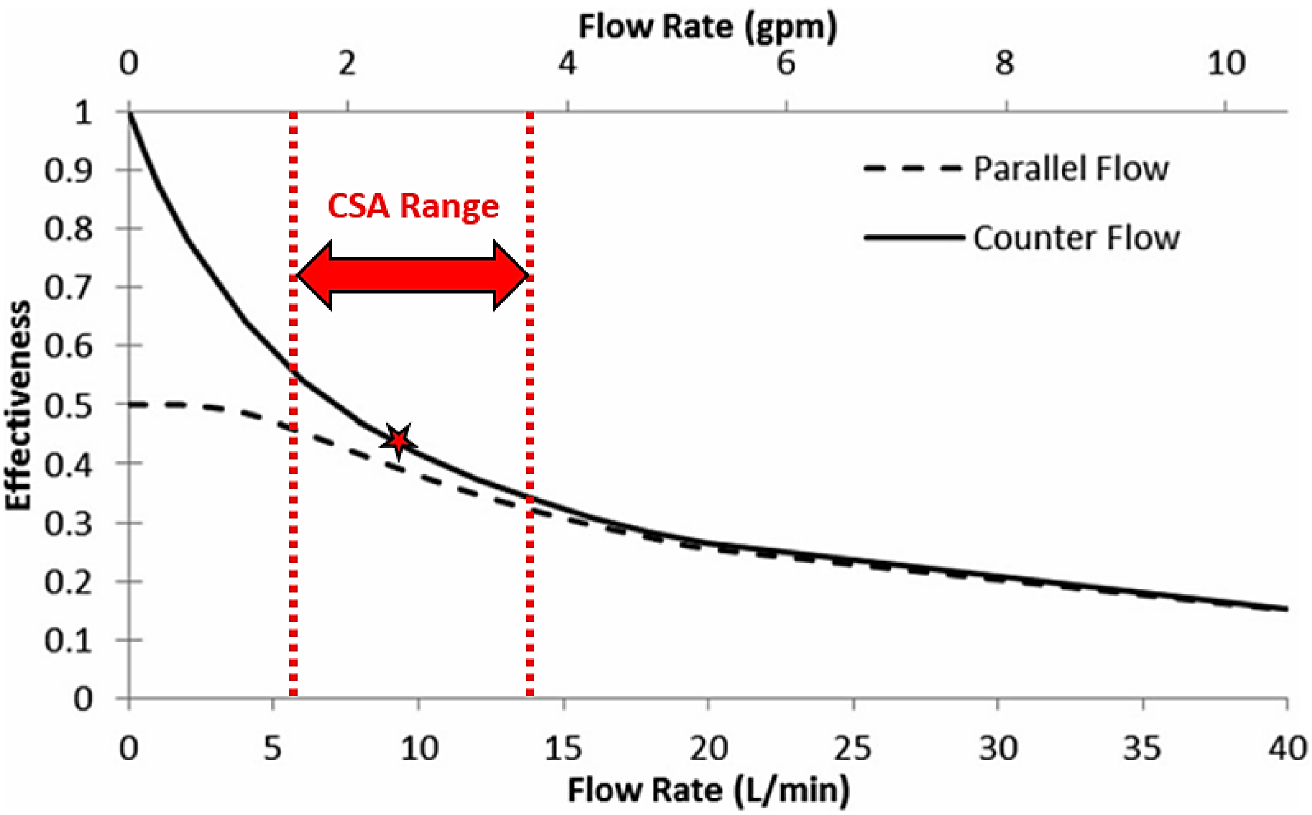

Figure 4: Effectiveness vs. flowrate curve for a DWHR heat exchanger operated at equal-flow. Figure adapted from [10].

Figure 5: An example of the sales label printed on commercially available DWHR heat exchangers.

2.1 Pros and Cons of the rated effectiveness

This section intends to highlight how the rated performance point should be used, how it is currently misused, and the implications this has on local building codes.

The rated point should only be considered as a metric for *generic* comparison between different DWHR heat exchangers; in other words, if the effectiveness value listed on the sales label for one product is of a higher magnitude than that of another product, it simply means that one product performed better during prescribed laboratory testing. The pressure drop is also provided, so that the potential buyers can determine whether or not the mains pressure in the dwelling is compatible with the heat exchanger size of their choosing.

The misconceptions associated with the rated performance point are more numerous than its uses. Firstly, the rated performance is not an estimate for the potential savings associated with each product. Secondly, the metric measured during the rated performance is effectiveness(ε); this metric is routinely mislabeled and mistaken with another widely-used performance metric, namely efficiency(η). Thirdly, having one performance point printed on the product is highly misleading, as it suggests that the heat exchanger is always operating under similar conditions that would result in the listed effectiveness value; this is simply false. Each of these misconceptions will be elaborated on in the following paragraphs.

The first and third misconceptions are related, and have to do with the lack of guidelines for predicting performance of DWHR heat exchangers under variable inlet conditions. This issue is not limited to these heat exchangers, and similar limitations exist for other heat exchangers. For example, in the context of heat recovery ventilators (HRVs), the associated performance metric is the sensible effectiveness measured at a prescribed equal-flow condition. Note that the equation used for calculating sensible effectiveness is identical to eq. 4. The issue with this approach is that if the inlet conditions, specifically the flow rates, do not match those used during laboratory testing, then the heat exchanger's effectiveness is no longer expected to match the rated value. In summary, despite the usefulness of the effectiveness metric in providing a point-comparison between different commercially available products, it is by definition a function of the inlet conditions listed in eq. 2; therefore, the effectiveness is not necessarily constant, nor can the rated value be readily modified to account for variable inlet conditions.

The second misconception is a historically prevalent issue revolving characterization of heat exchangers; it is the blatant misuse of the term efficiency, η, instead of heat exchanger effectiveness, ε. This issue is not new, and has been pointed out previously in heat exchanger literature [1, 11]. To elaborate, the term efficiency is often used when one form of energy is being converted to another form of energy; alternatively, efficiency is sometimes used to quantify performance compared to ideal performance under the same conditions. In contrast, the term effectiveness has a special meaning when used in the context of heat exchangers, and it is purely based on the transfer of thermal energy between the fluid media within a heat exchanger. Additionally, heat exchanger effectiveness measures the ratio of actual heat transfer rate, under specific inlet conditions, to the maximum (not ideal) heat transfer rate under the same inlet conditions. The important distinction here is that the maximum heat transfer rate in this definition would only occur if the heat transfer coefficients or heat transfer areas were *infinite*. In other words, the conditions that would result in the maximum heat transfer rate are neither ideal nor are they necessarily attainable for a given heat exchanger. In short, efficiency and effectiveness are different concepts that should not be used interchangeably, especially in the context of heat exchangers.

This misconception may seem harmless at first, but it has serious consequences. It is a preconceived notion that higher *efficiency* is associated with higher savings; however, this is not necessarily true for heat exchanger *effectiveness*. This is perhaps best conveyed through an example. Table 1 shows measured performance data for a DWHR heat exchanger tested under equal and unequal flow conditions; the flowrates correspond to different combinations of 5.5 and 14L/min, that were imposed on different sides of the heat exchanger during testing. Note that the heat exchanger effectiveness changed significantly based on flowrates, and that a higher effectiveness did not result in a higher heat transfer rate for the heat exchanger that was tested. This is due to the definition of heat exchanger effectiveness, and the presence of the term $\dot{C}_{min}$ in the denominator for eq. 2. Further examples and data can be found a past publications by Manouchehri [12, 13].

Table 1: Measured performance data for a 3" diameter, 60" long DWHR unit. Data from Table A-15 in [13].

$\dot{V}_{cold}(L/min)$	$\dot{V}_{hot}(L/min)$	$\varepsilon(\%)$	$\dot{q}_{measured}(kW)$
5.5	5.47	62.4	6.59
5.5	13.99	78.7	8.48
13.99	5.5	75.5	8.16
14.05	13.97	45.5	12.51

Lastly, the rated performance point does not account for the plumbing configuration where DWHR units are installed. This reiterates the fact that heat exchanger effectiveness is a function of operating conditions for a given heat exchanger, and that the rated performance point does not account for realistic operating conditions. To elaborate on this, Figure 6-R was created to show a simplified plumbing schematic for a dwelling that does not contain a DWHR heat exchanger. In this figure, blue lines (**—CW—**) indicate that water is at mains temperature, red lines (**—HW—**) indicate that water is at the same temperature as the hot water tank, and purple lines (**—TW—**) indicate that water temperature is somewhere between the mains temperature and hot water tank's temperature. The green lines (**—DW—**) represent the drainpipes in this system. Figure 6-A, Figure 6-B and Figure 6-C were then created to highlight three distinct options for addition of a DWHR heat exchanger to this plumbing system. For the first option (Figure 6-A), all preheated water is directed to the hot water tank. For the second option (Figure 6-B), all preheated water is sent directly to fixtures, and the third option (Figure 6-C) is a combination of options A and B.

Note that the only option that allows for the possibility of having *equal* flowrates through the heat exchanger is option C, and the performance metrics produced through CSA B55.1 are only relevant for this option. This is a significant limitation because plumbing configurations are influenced by builders and codes, etc. For example, in the province of Quebec [14], only option A is allowed; the rationale behind this is to avoid any harmful bacteria (such as Legionella) from bypassing the hot water tank. On another note, depending on the size of the residential dwelling, state of retrofit, physical clearances, etc., it is not always possible to aim for option C. Lastly, the requirements regarding mixing-valves in some jurisdictions further exacerbates this issue. In summary, the flowrates through DWHR heat exchangers, and their associated performance, are directly influenced by plumbing systems in which they are installed. However, CSA B55.1's scope is limited to option C, making the rated point inapplicable to many installations.

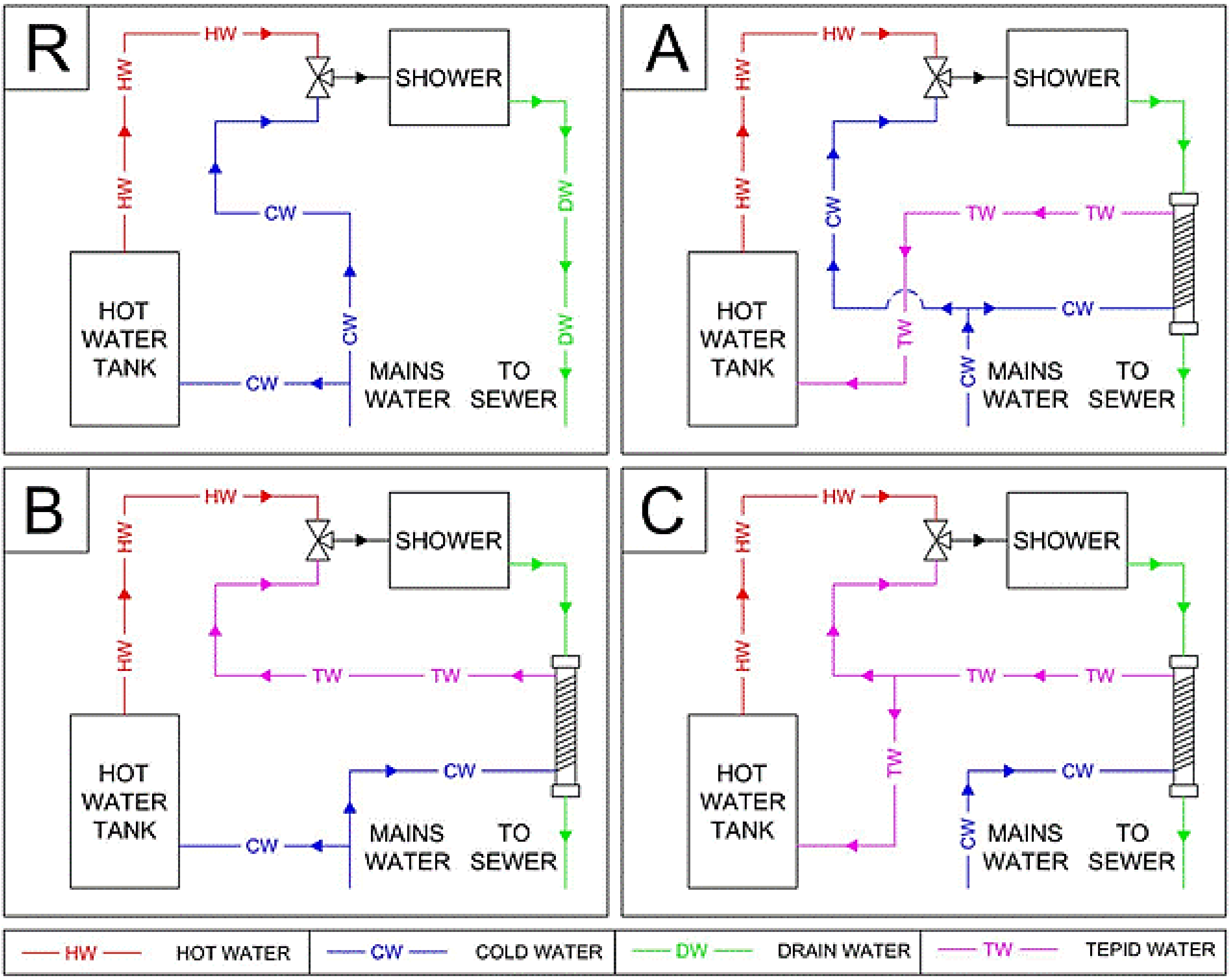

Figure 6: Simplified plumbing configurations, showing layouts with and without DWHR heat exchangers. Configuration (R) depicts a setup without a DWHR heat exchanger, (A) depicts all preheated water being sent to the water heater, (B) depicts all preheated water being sent directly to the fixtures, and (C) depicts a combination of (A) and (B).

2.2 Canadian Codes and Standards

An aspect of CSA B55.1 that bears further discussion is the modifications applied to the latest version of the standard in 2020. In the older iterations of the standard, more specifically versions 2012 and 2015, only vertical (falling-film) heat exchangers were considered as DWHR heat exchangers. However, the newest version of the standard has extended the testing methodology and certification process to include near-horizontal DWHR heat exchangers as well. This allows for expansion of the technology and promotes innovative designs. Unfortunately, local codes and regulations in Canada have not been updated to account for near-horizontal variations of DWHR heat exchangers; hence, many such products are not allowed per building codes. In short, an entire classification of heat exchangers has been incorporated into the newest version of the CSA standard covering DWHR units, but these changes have not been accounted for in the building codes, as will be discussed shortly.

The National Building Code of Canada (NBC2020) specifies that DWHR units must adhere to CSA B55.1-15, and clause 9.36.5.12.(2) specifically mentions that efficiency of these heat exchangers must be modelled based on the same physical configuration intended for their installation [15]. This is perhaps the most up-to-date approach to implementation of DWHR heat exchangers in residential dwellings, as it specifically stipulates that the efficiency has to be based on the intended installation. However, it fails to acknowledge the fact that the CSA standard does not produce any data to address this need, nor does it provide any procedures for estimating performance under conditions that deviate from rated conditions. It bears repeating that despite the consistent use of the word efficiency in codes/standards, the correct metric is heat exchanger effectiveness. On another note, NBC-2020 refers to an older edition of the CSA standard, namely CSA B55.1-15 [3], instead of the latest edition published under CSA B55.1-20 [4]. This was explained previously, but in short, the main difference between these two versions of the CSA standard is that the latest standard incorporates near-horizontal DWHR heat exchangers and allows for their certification. In summary, NBC-2020 in its current form does not allow for installation of near-horizontal DWHR heat exchangers, nor does it provide a procedure for estimating performance based on intended installations.

In Ontario, DWHR heat exchangers are listed as part of the supplementary standard SB-12 [16], which covers energy efficiency for housing. There are multiple clauses (2.1.1.11. and 3.1.1.12.) in SB-12 that mention DWHR units specifically, and their content can be summarized as follows:

- The heat exchanger shall meet a minimum efficiency of 36% or 42%, depending on the subclause being pursued
- Be installed in an upright position (±5° from vertical)
- Cold (mains) water shall be connected to the bottom inlet of the vertically installed heat exchanger (i.e. the flow arrangement for the heat exchanger shall be counter-flow)

These constraints were implemented into the code prior to the publication of the latest CSA standard B55.1-20; hence, the code only allows for vertical (falling-film) DWHR heat exchangers. This issue must be addressed before near-horizontal DWHR heat exchangers and other innovative designs can be employed in jurisdictions such as Ontario. It is important to note that the minimum efficiency requirement listed in SB-12 is also based on typical performance for vertical heat exchangers. It is well-known that near-horizontal DWHR heat exchangers are much less effective than their vertical counterparts (assuming they have the same size). In other words, near-horizontal DWHR heat exchangers must be very large in size in order to meet the minimum efficiency that is currently stipulated in SB-12. In summary, the latest version of the supplementary standard SB-12 is quite limiting and holds an outdated perspective on what qualifies as a DWHR heat exchanger. This restricts creative designs and prevents the use of these heat exchangers in homes where vertical installation cannot be done.

The latest building codes in other jurisdictions across Canada do not specifically mention DWHR heat exchangers. This is perhaps due to the inconsistencies and misconceptions surrounding DWHR technology, and the severe lack of modelling tools to support implementation of such heat exchangers on a large scale.

3. DWHR Landscape

This section was prepared to complement this report using a list of commercially available DWHR products. The content presented here was compiled in April 2024, and the list of commercially available products is expected to change over time. In total, there were 53 products available on the Canadian market (as of April 2024). A total of 43 products are designed for vertical installation, while a total of 10 products are intended for near-horizontal installation. Figure 7 shows the rated performance of all 53 products in terms of their reported effectiveness, sorted in an ascending order. Note that reported effectiveness values are measured under equal-flow conditions, and the exact flow rates for each case can be slightly different depending on the manufacturer. A complete list of all 53 products, along with their associated manufacturers and tests conditions can be found in Appendix A. As a side-note, out of the 53 products, only 10 are considered near-horizontal or horizontal, and only 3 of those meet the 42% metric listed in SB-12. This serves as a reminder that local codes, such as SB-12, have not been updated to account for the near-horizontal designs; hence, they act as unintended barriers against new designs.

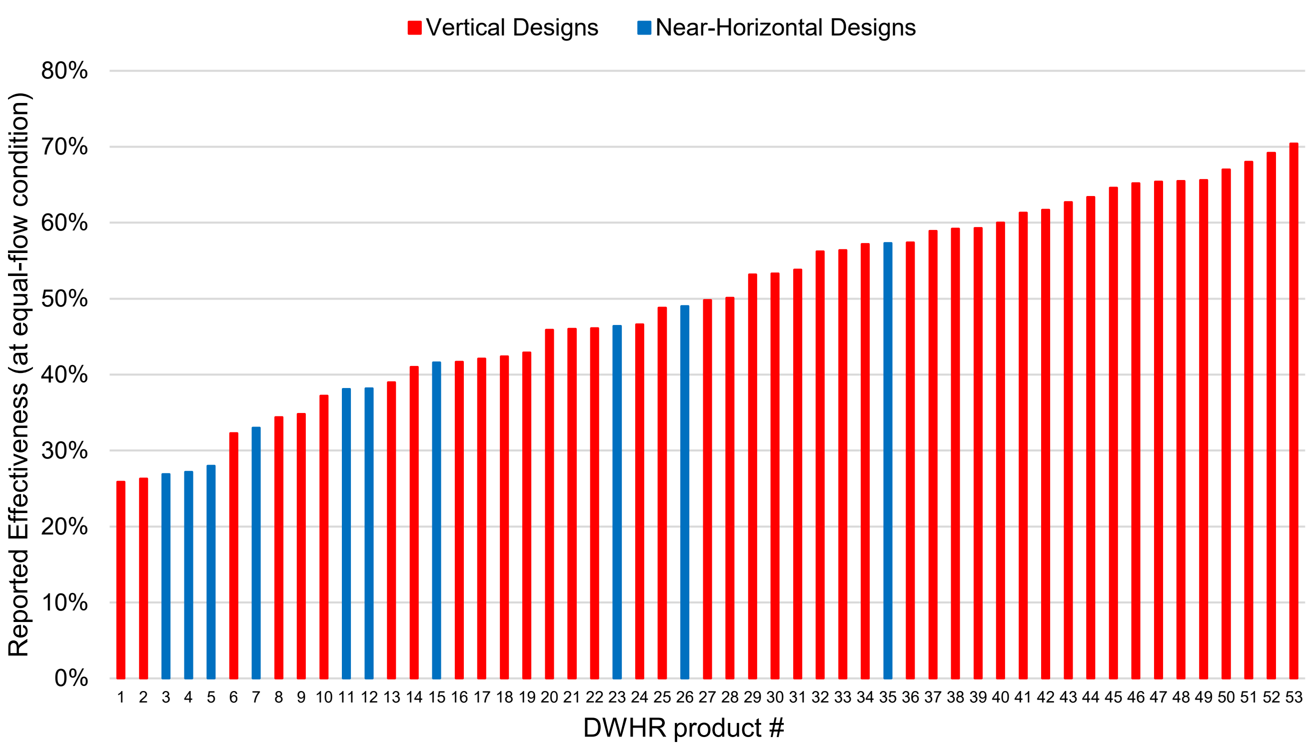

Figure 7: Overview of commercially available DWHR products as of April 2024. Products were sorted in order of ascending effectiveness. Dataset can be found in Appendix A.

Several statistical remarks can be made based on the data from Figure 7. Firstly, most of the commercially available products, including the highest performing ones, are of vertical design. Secondly, near-horizontal designs are, on average, less effective compared to vertical designs. Additionally, all of the near-horizontal products presented here are produced by European manufacturers; this can be attributed to the following three issues:

1. CSA standard B55.1-20 has only recently implemented near-horizontal DWHR units, and the building codes across Canada have yet to be updated to include them.
2. Any DWHR heat exchanger that can legally be sold in Canada must be rated according to CSA B55.1; however, due to outdated building codes that require DWHR heat exchangers to be installed vertically, Canadian manufacturers are effectively locked out of the market for design and sale of near-horizontal DWHR units.
3. Ontario building code’s SB-12 specifies arbitrary minimum efficiencies for DWHR heat exchangers. These arbitrary values were implemented into the building code prior to the publication of the latest CSA standard, and as such, only correspond to vertical units. Given that the near-horizontal variations are, on average, less effective at providing energy savings, Canadian manufacturers are effectively forced to focus on design and sale of vertical units that can meet minimum efficiencies stipulated in the code.

4. Conclusions

This report aimed to offer an understanding of DWHR heat exchangers and pinpoint the challenges related to their implementation in Canada. It highlighted various issues, differing in severity, that affect the overall adoption of DWHR technology across the country.

Firstly, the phrase drain water heat recovery is misleading when applied to this technology; these heat exchangers are designed for recovering heat from showers, or other fixtures having simultaneous water draw and drainage. Furthermore, the definition of drain water in the context of DWHR does not include black water. Therefore, much of the water that traverses down the drain in a residential dwelling is excluded from the current definition of DWHR heat exchangers, which misleads those unfamiliar with the technology. Secondly, the term efficiency has been incorrectly used instead of the term heat exchanger effectiveness, in all relevant codes and standards in Canada. This is a prevalent issue with heat exchangers in general, and leads to further confusion for those wishing to incorporate DWHR technology in their designs.

The latest version of CSA standard B55.1-20, which covers thermal performance of DWHR heat exchangers, has been updated to include horizontal designs as well as vertical ones. This is a significant change that has added an entire classification of heat exchangers to the certification process; however, no jurisdictions in Canada have reflected this change in their local building code. On the contrary, Ontario Building Code's SB-12 requires DWHR units to be installed vertically, which disqualifies all horizontal designs regardless of performance. On a similar note, SB-12 specifies minimum efficiencies for heat exchangers that can be installed in residential dwellings, and given the fact that horizontal units are, on average, much less effective than their vertical counterparts, SB-12 is highly exclusionary towards near-horizontal designs.

Lastly, the performance of a DWHR heat exchanger is a strong function of flowrates on either side of the heat exchanger. These flowrates are influenced by the occupant, shower fixture, shower temperature, local codes, and the plumbing configuration in a given residential dwelling. In other words, the thermal performance for DWHR heat exchangers cannot be assumed to stay constant under different operating conditions. The heat exchanger effectiveness that is measured as part of CSA B55.1 is only applicable to one particular plumbing configuration and flowrate, and this measured performance-point is not representative of DWHR performance for any other conditions/installations. In other words, the effectiveness value that is printed on a DWHR product's sales label is completely decoupled from realistic installations, and only provides a means for a generic comparison of commercially available products.

References

[1] R. K. Shah and D. P. Sekulić, Fundamentals of Heat Exchanger Design, John Wiley & Sons Inc., 2003.

[2] CSA, "B55.1:12-Test method for measuring efficiency and pressure loss of drain water heat recovery units," The Canadian Standards Association, 2012.

[3] CSA, "B55.1:15-Test method for measuring efficiency and pressure loss of drain water heat recovery units," The Canadian Standards Association, 2015.

[4] CSA, "B55.1:20-Test method for measuring efficiency and pressure loss of drain water heat recovery units," The Canadian Standards Association, 2020.

[5] CSA, "B55.2:12-Drain water heat recovery units," The Canadian Standards Association, 2012.

[6] CSA, "B55.2:15-Drain water heat recovery units," The Canadian Standards Association, 2015.

[7] CSA, "B55.2:20-Drain water heat recovery units," The Canadian Standards Association, 2020.

[8] P. Tardif, Interviewee, *Photograph of drain water heat recovery installed in one of the test houses in NRC.* [Interview]. 2 May 2024.

[9] W. M. Kays and A. L. London, Compact heat exchangers, 2nd Edition ed., New York: McGraw-Hill Book Co, 1964.

[10] M. R. Collins, G. W. E. Van decker and J. Murray, "Characteristic effectiveness curves for falling-film drain water heat recovery systems," *HVAC&R Research,* vol. 19, no. 6, pp. 649-662, 2013.

[11] S. Kakaç and A. E. Bergles, Low Reynolds number flow heat exchangers, Washington: Hemisphere Pub. Corp., 1983.

[12] R. Manouchehri and M. R. Collins, "An experimental analysis of the impact of unequal flow on falling film drain water heat recovery system performance," *Energy and Buildings,* vol. 165, pp. 150-159, 2018.

[13] R. Manouchehri, Predicting Steady-State Performance of Falling-Film Drain Water Heat Recovery Systems from Rating Data, Waterloo: UWSpace, 2015.

[14] Régie du bâtiment du Québec, "Branchement des systèmes de récupération de chaleur des eaux de drainage : attention aux légionelles," March 2013. [Online]. Available: https://www.rbq.gouv.qc.ca/domaines-dintervention/plomberie/interpretations-et-directives-techniques/branchement-des-systemes-de-recuperation-de-chaleur-des-eaux-de-drainage-attention-aux-legionelles/. [Accessed April 2024].

[15] C. C. o. B. a. F. Codes, "National Building Code of Canada," National Research Council of Canada, Ottawa, 2020.

[16] M. o. M. A. B. a. D. Branch, "MMA Supplementary Standard SB-12 Energy Efficiency For Housing," Queen's Printer for Ontario, 2016.

[17] I. Henderson, "Drain Water Heat Recovery Landscape," National Resources Canada, Ottawa, 2024.

[18] Environment Protection Authority South Australia, "Black and grey water management," 2024.

Appendix A: List of available DWHR products

This appendix contains a list of DWHR heat exchangers available in North America and Europe as of April 2024. The products are listed in order of ascending effectiveness in Table A1, noting that the reported effectiveness is tied to a flowrate, and this flow rate is inconsistent across the industry. It is also worth noting that all of the reported data correspond to tests where the flow rates through the heat exchanger were equal (i.e. only configuration C from Figure 6).

Table A1: List of commercially available DWHR products as of April 2024. Data taken from [17], and manufacturers' websites.

Product #	Product Name	Manufacturer	Design Type	Reported Effectiveness	Flowrate (L/min)
1	R2-30	Renewability Energy Inc	Vertical	25.9%	9.5
2	R3-24	Renewability Energy Inc	Vertical	26.3%	9.5
3	Joulia Inline 3P-630	Showersave	Horizontal	26.9%	9.2
4	HORIZONTAL SHRU	Heatrae Sadia	Horizontal	27.2%	9
5	iZi 30	Zypho	Horizontal	28.0%	9.2
6	R4-24	Renewability Energy Inc	Vertical	32.3%	9.5
7	iZi 40	Zypho	Horizontal	33.0%	9.2
8	X2-36	Renewability Energy Inc	Vertical	34.4%	9.5
9	R3-30	Renewability Energy Inc	Vertical	34.8%	9.5
10	R4-30	Renewability Energy Inc	Vertical	37.2%	9.5
11	Recoup Drain+Compact	Recoup	Horizontal	38.1%	9.2
12	Joulia Inline 5P-630	Showersave	Horizontal	38.2%	9.2
13	R3-36	Renewability Energy Inc	Vertical	39.0%	9.5
14	TDH3320B-DR	EcoInnovation	Vertical	41.0%	9.5
15	Recoup Drain+Duo	Recoup	Horizontal	41.6%	9.2
16	R4-36	Renewability Energy Inc	Vertical	41.7%	9.5
17	TDH3335B-DR	EcoInnovation	Vertical	42.1%	9.5
18	X2-48	Renewability Energy Inc	Vertical	42.4%	9.5

19	R3-42	Renewability Energy Inc	Vertical	42.9%	9.5
20	R4-42	Renewability Energy Inc	Vertical	45.9%	9.5
21	TD442B-DR	EcoInnovation	Vertical	46.0%	9.5
22	TDH3395B-DR	EcoInnovation	Vertical	46.1%	9.5
23	Recoup Easyfit+	Recoup	Horizontal	46.4%	9.2
24	R3-48	Renewability Energy Inc	Vertical	46.6%	9.5
25	X2-60	Renewability Energy Inc	Vertical	48.8%	9.5
26	Slim 50	Zypho	Horizontal	49.0%	9.2
27	R4-48	Renewability Energy Inc	Vertical	49.8%	9.5
28	R3-54	Renewability Energy Inc	Vertical	50.1%	9.5
29	R4-54	Renewability Energy Inc	Vertical	53.2%	9.5
30	R3-60	Renewability Energy Inc	Vertical	53.3%	9.5
31	X2-72	Renewability Energy Inc	Vertical	53.8%	9.5
32	R3-66	Renewability Energy Inc	Vertical	56.2%	9.5
33	R4-60	Renewability Energy Inc	Vertical	56.4%	9.5
34	TDH3620B-DR	EcoInnovation	Vertical	57.2%	9.5
35	Recoup Drain+Duo HE	Recoup	Horizontal	57.3%	9.2
36	Pipe60	Zypho	Vertical	57.4%	9.2
37	R3-72	Renewability Energy Inc	Vertical	58.9%	9.5
38	R4-66	Renewability Energy Inc	Vertical	59.2%	9.5
39	VERTICAL SHRU	Heatrae Sadia	Vertical	59.3%	9.2
40	Recoup Pipe HEX RD	Recoup	Vertical	60.0%	9.2
41	R3-78	Renewability Energy Inc	Vertical	61.3%	9.5
42	R4-72	Renewability Energy Inc	Vertical	61.7%	9.5
43	Pipe65	Zypho	Vertical	62.7%	9.2
44	R3-84	Renewability Energy Inc	Vertical	63.4%	9.5

45	Showersave QB1-21	Showersave	Vertical	64.6%	9.2
46	Recoup Pipe HEX	Recoup	Vertical	65.2%	9.2
47	R3-90	Renewability Energy Inc	Vertical	65.4%	9.5
48	R4-84	Renewability Energy Inc	Vertical	65.5%	9.5
49	Showersave QB1-21C	Showersave	Vertical	65.6%	9.2
50	R3-96	Renewability Energy Inc	Vertical	67.0%	9.5
51	R4-96	Renewability Energy Inc	Vertical	68.0%	9.5
52	Pipe75	Zypho	Vertical	69.2%	9.2
53	Showersave QB1-21D	Showersave	Vertical	70.4%	9.2