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MASTER PLANNING & DECISION GUIDE FOR NATURAL GAS MECHANICAL SYSTEMS

Procedure for Builders and Mechanical Designers to quickly define the type of system that is needed.

LEEP LOCAL ENERGY EFFICIENCY PARTNERSHIPS

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INTRODUCTION

"The Guide is an important tool to help builders know what to do next with the HVAC system to improve comfort and efficiency, while maintaining affordability for homebuyers."

John Meinen, Builder, Pinnacle Quality Homes

"The Guide takes the guesswork out of offering better systems to my clients. At the end of the process, my client knows what to expect and I know what to design."

Dara Bowser, Mechanical Designer, Bowser Technical Inc.

Why Builders need the GUIDE

Builders want HVAC system designs that:

- Address changes in housing form, style, design and construction that have changed the mechanical needs of today's housing,
- Improve homebuyer comfort and help manage their energy costs,
- Provide saleable benefits that are easy to understand by the home buying public, and
- Help manage the risk of call-backs in a market with heightened customer expectations, while simultaneously control costs associated with the HVAC system design.

Why Mechanical Designers need the GUIDE

Designers need the GUIDE to:

- Facilitate discussion and collaborative decision making with their builder clients, aimed at delivering HVAC system designs that address builder goals.
- Provide rationale for changing HVAC system design features from "business as usual" to new approaches that focus on builder goals and deliver new benefits and value to the homebuyer.
- Establish a structured review process to record design requirements which will "best satisfy" builder-specific goals. This process gives the designer permission to make design changes that can improve comfort, efficiency and aesthetics. It enables the designer to move forward with the detailed mechanical system design.

What the GUIDE Delivers

The Master Planning & Decision Guide ("GUIDE") allows builders and their mechanical designers to:

- Collaborate on key HVAC system design decisions to address specific needs, important to fulfilling builder goals, which will improve the performance, comfort and overall value delivered by the new home.
- Identify key HVAC design features needed to mitigate the most important issues related to a specific builder, their housing designs and local marketplace requirements.
- Leverage their efforts, by transferring "lessons-learned" from one GUIDE-design process to all other houses in a development.

The GUIDE in Action

The **Mechanical System Decision Guide** is intended for use by both builders and their mechanical designers to define, communicate, discuss and finalize key design features for natural gas, forced-air heating and central cooling systems as illustrated in Figure 1.

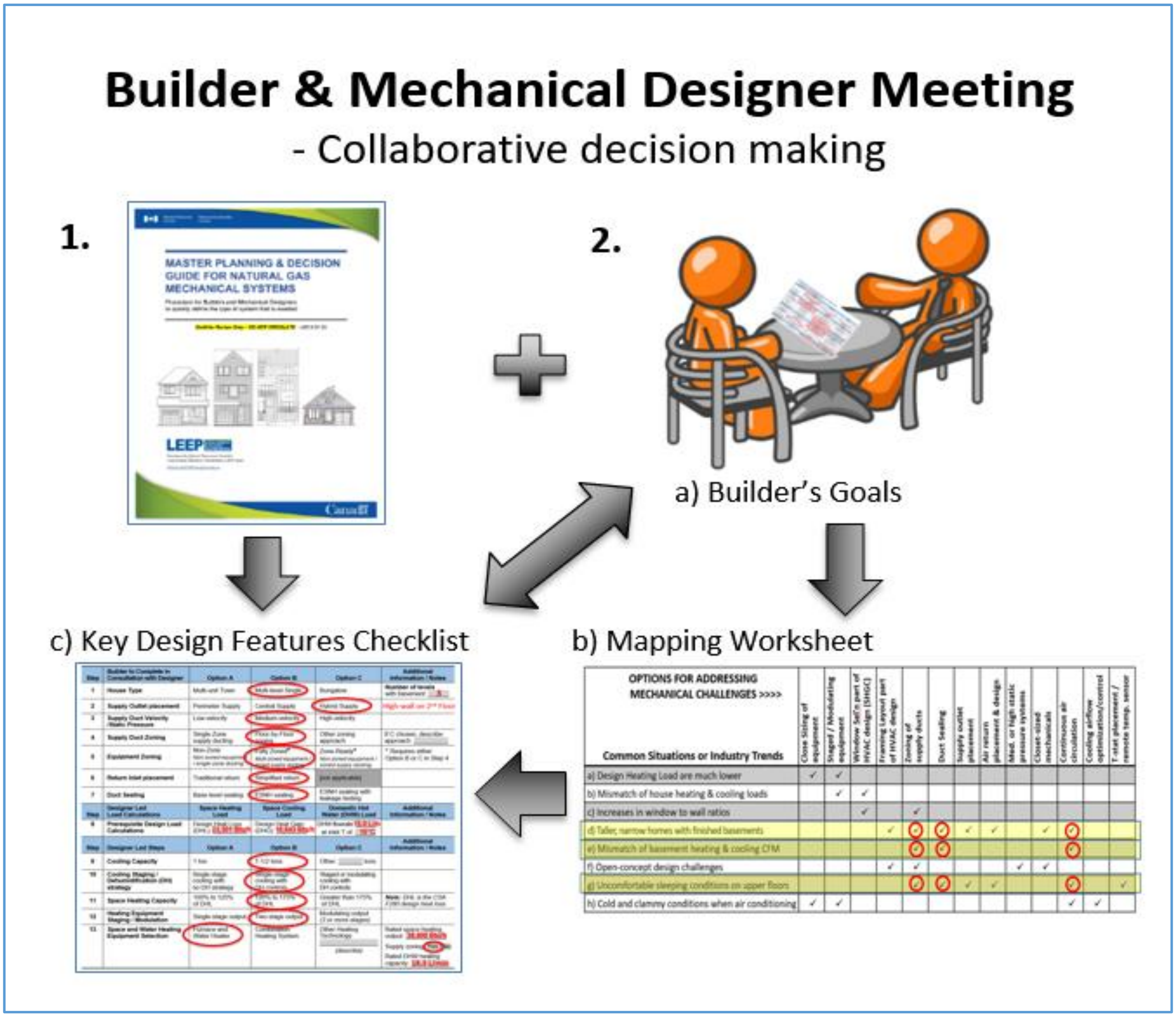


Figure 1: Collaborative decision making by builders & mechanical designers results in superior HVAC system designs

Major steps in this **collaborative decision making process** include:

a) Identifying builder goals,

b) Mapping builder goals to priority design options,

c) Finalize key design features for a natural gas, forced-air heating and central cooling system.

How to Get Started

The **collaborative decision making process** may be initiated by either the builder or the mechanical designer.

1. **BUILDER Initiated Collaborative Design:** Builders are encouraged to become familiar with the content of the GUIDE and the impacts that various design options can have on performance and value provided by the HVAC system. Builders may want to record their preferences for some of the earlier decision steps (e.g. possibly up to Step 7) on the "**Key Design Features Checklist**" *(see Appendix C for a blank copy of the checklist)*.

   Builders can then contact their mechanical designer to setup a builder-designer meeting to review the partially completed checklist and make adjustments as necessary. A **"Mapping Worksheet"** *(see Appendix A for a blank copy of the worksheet*) may be used to help identify priority design options which target specific builder goals.

   The designer will completed the remaining GUIDE steps and record selected options on the "**Key Design Features Checklist.**

2. **MECHANICAL DESIGNER Initiated Collaborative Design:** In this approach the mechanical designer will initiate the meet and discussion of builder goals for the housing development. A **"Mapping Worksheet"** *(see Appendix A for a blank copy of the worksheet)* may be used to help identify priority design options which target specific builder goals.

   Using these priority design options, the designer will complete all GUIDE Steps and record the required options on the "**Key Design Features Checklist"** *(see Appendix C for a blank copy of the checklist)*.

In either approach, **lesson-learned** from the collaborative design of one house can be leverage by the mechanical designer and adapted to other housing models in the housing development.

An example of how the collaborative decision making process can work is provided in the following sections for a case study house.

Identifying builder goals and mapping to priority design options

Builders are encourage to develop a specific list of goals and priorities that focus on improving the HVAC system design for each of their housing projects. Support information is provided in Appendix A for this specific purpose.

In this case-study example, the builder has provided the following information and priorities for the development *(Note: Your specific goals may be different):*

- House designs are tall and narrow with finished basements, open-concept main floors and bedrooms on the top floor.
- Preference to improve the quality and comfort offered in the finished basement.
- Summer cooling performance in top-floor bedrooms is important for homebuyer satisfaction, and to manage call-back risks.
- Provide saleable benefits which can be easily understood by the average homebuyer.

During the builder / designer meeting, the builder goals were mapped to identify a list of priority design options for consideration during the HVAC design process, which include:

- Zoning of supply ducts,
- Duct Sealing,
- Supply outlet placement, and
- Air return placement and design.

Additional details on the mapping process and a blank copy of the **Mapping Worksheet** are provided in Appendix A.

Finalizing HVAC System Key Design Features

Using the GUIDE process, the builder and designer worked together to develop a design for a "best-fit" HVAC system. Key features of the **collaborative design** are summarized and compared to the **business-as-usual design** in Table 1.

Table 1: Comparing Collaborative Design Approach to Business-as-Usual Design

Business-as-Usual Design Approach	Collaborative Design Approach	Rationale for Change / Value offered
Perimeter supply outlets	Hybrid supply, with high-wall outlets on the upper bedroom level	- High wall outlets improve upper level cooling performance - Moving supply outlets off the floor "reduces the HVAC system footprint" by allowing more flexible furniture placement.
Low-velocity ducting with rectangular supply trunks	Mid-velocity ducting with round supply trunks	- Smaller ducting eliminates most bulkheads and most box-outs, and is easier to integrate into house designs. - Round trunks are easier to seal, and reduced duct leakage will improve summer comfort in both the basement and top floors.
Single-zone supply ducting	Zoned supply ducting with one zone per floor	- Zoning will reduce temperature stratification between floors; improve temperature uniformity in the basement from winter to summer, and improve cooling performance in bedrooms. - Zoning also provides the homebuyer with new feature to manage energy usage through use of individual zone setback.
Traditional design with returns in all rooms	Simplified return design with 1 high return, 1 low return, and others as required	- Simplified air return design helps to improve temperature uniformity between floors, and require less stacked wall space which is easier to accommodate in open-concept house designs.
Ducting / Cooling Capacity: 800 CFM with 2 ton A/C	Ducting / Cooling Capacity: 600 CFM with 1-1/2 ton A/C	- With collaborative design, information is available and fewer assumptions are necessary by the HVAC designer, allowing optimization of cooling capacity and reduction in duct sizing, and associated costs.
Single-stage Furnace: 38,400 Btu/h output	Two-stage Furnace: 23,000 / 38,400 Btu/h outputs	- Two-stage furnace will address builder goals for enhance performance; works better with the multi-zone duct system. - Cost of going to two-stage furnace is offset by A/C savings.

Additional details on this example-use of the GUIDE and the collaborative decision making process are provided in Appendix B.

Delivering on Builder Requirements

Table 2 summarizes how well the **collaborative design approach** addresses the Builder's goals for the development.

Table 2: How the Collaborative HVAC Design Process Delivers on Builder's Goals

Builder Goals	How Collaborative Design Approach Addresses Builder Goals
HVAC systems that work better with today's housing designs	- Mid-velocity, lower capacity duct system all but eliminates the need for bulkheads and box outs. - Simplified air-return design require less stacked vertical wall space, which is easier to accommodate in open-concept house designs. - Moving supply outlets off the floor "reduces the HVAC system footprint" by allowing more flexible furniture placement.
Improve homebuyer comfort and help manage their energy costs	- Zoning, with one thermostats per floor, provides superior temperature control in summer and winter throughout the home. - Zoning controls will automatically adjust supply airflow to the basement to prevent overcooling in summer, while providing excellent comfort in winter. - Duct sealing will reduce air leakage and improve air distribution to enhance both heating and cooling on upper levels, and prevent overcooling in the basement. - Zoning provides new opportunities for energy management through use of zone setbacks, while maintain maximum comfort in other occupied areas of the home.
Provide saleable benefits that are easy to understand by the home buying public	- Living space is enhance by compact duct design which eliminates most bulkheads and box-outs, freeing up floor area and improving basement headroom; High-wall supply outlets in bedrooms allow more flexible furniture placement. - Providing one thermostat per floor provides homebuyers with superior temperature control in summer and winter, and provides new energy management opportunities through zone setback. - Two-stage furnace provides superior load matching during the heating season, and may contribute to improved temperature uniformity throughout the house.
Help manage the risk of call-backs in a market with heightened customer expectations, while simultaneously managing HVAC system costs.	- All comfort improvements, listed above, will help manage builder's risk of call-backs. - Costs are managed and controlled by: Reducing A/C condenser size by 0.5 tons; Downsizing supply ducting by 200 CFM; Using a simplified return; and, Eliminating bulkheads and box-outs. - Some offsetting costs, which help manage call-back risks and provide saleable benefits are associated with the zoning equipment and two-stage furnace used in this design.

Scope of the Mechanical System Decision Guide

The focus of this Guide is on mechanical system designs:

- Using natural-gas space heating appliances such as forced-air furnaces or combination space and water heating systems.
- Using forced-air duct designs implemented with low, medium or high-velocity ducting that operates at total external static pressures (ESP) ranging from less than 0.5 inch water column (WC) to greater than 1.0 inch WC.
- With supply ducting configured as either:
  - Single-zone (whole-house) supply, or
  - Multiple zones that divide at the supply plenum to service "roughly equal" heating zones in different areas of the home.

OVERVIEW OF MECHANICAL SYSTEM DECISION GUIDE STEPS

The steps in this equipment decision process are:

Builder to Complete in Consultation with Designer:

STEP 1: Identify Type of House

STEP 2: Choose Supply Outlet Placement

STEP 3: Choose Supply-Duct Velocity / Static Pressure

STEP 4: Choose Supply Duct Zoning

STEP 5: Choose Equipment Zoning

STEP 6: Choose Return Inlet Placement

STEP 7: Choose Duct Sealing Level

Designer Led Load Calculations:

STEP 8: Prerequisite Load Calculations

Designer Led Steps:

STEP 9: Size Cooling Capacity

STEP 10: Choose Dehumidification Strategy; Staging and Modulation - Cooling Mode

STEP 11: Determine Space Heating Size Range

STEP 12: Choose Equipment Staging and Modulation – Heating Mode

STEP 13: Choose Space and Water Heating Equipment

How the Decision Guide works

- **Each STEP** of the decision process provides you with **2 or 3 options**
- Use the **short description** to help you select which option **"best fits"** your specific requirements.
- Use the **Key Design Features Checklist** as an easy way to record your decisions. This one-page checklist is provided in **Appendix C** at the end of this document.

STEP 1: IDENTIFY TYPE OF HOUSE

The type and size of house being built will help determine the number and arrangement of HVAC zones required to provide the enhanced comfort control and energy-saving flexibility made possible by zoning a home.

Option 1A: Low-rise attached houses

This housing type includes various forms of low-rise attached housing such as:

- semi-detached, duplex, triplex, fourplex
- multi-level, row towns, and
- stacked, back-to-back towns.

The number of floors can range from one to four or more, including basements.

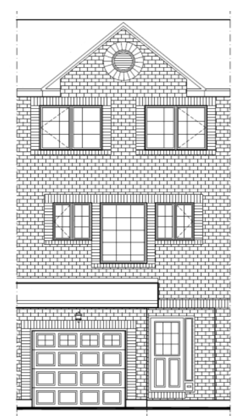


Figure 2: Example of multi-level townhouse

Option 1B: Multi-level, detached houses

This housing type includes single-family, detached homes with three or more floors, including basements.

Figure 3: Example of multi-storey detached

Option 1C: Single-storey, detached houses

This housing type applies to bungalow designs with up to two floors, including basements, which have distinctly different occupancy usage (e.g. cooking and living versus sleeping) on a single level

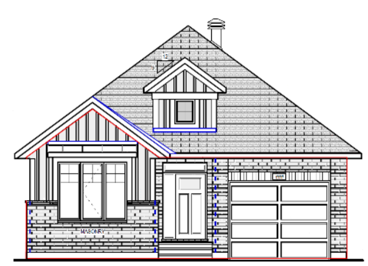


Figure 4: Example of a single-storey detached

STEP 2: CHOOSE SUPPLY OUTLET PLACEMENT

Supply outlet placement can influence:

- *Cooling performance on upper floors and*
- *Effect the amount of ductwork that needs to be installed in the home.*

Option 2A: Perimeter supply design

The **perimeter supply** design represents the majority of *"current practice"* and primarily uses:

- Perimeter floor outlets, and
- Ceiling outlets (e.g. in basements) as shown in Figure 5.

Advantages of the perimeter supply design may include:

- Familiar approach used by most designers;
- Employs commonly used installation methods.

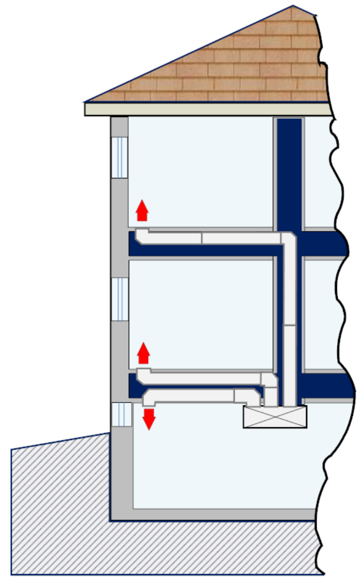


Figure 5: Perimeter supply design

Option 2B: Central supply design

The **central supply** option deviates from traditional design practice as illustrated in Figure 6. It can include:

- Supply trunks and branches that are located more centrally within the structure of the house;
- Supply outlets are located high on interior walls blowing air horizontally across the top of rooms as shown in Figure 6.

Advantages of the central supply option may include:

- Reduced duct lengths contributing to reduced ducting costs;
- High wall supply outlets that provide cool air at ceiling level on upper floors;
- Supply outlets on the walls or ceilings which do not interfere with furniture placement.

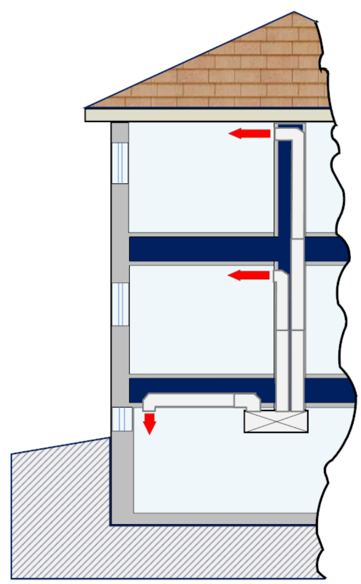


Figure 6: Central supply design

Additional planning for implementing central supply designs may include:

- Some changes to duct design practices commonly used by mechanical designers;
- The use of different ducting materials and/or grille/diffuser types; and,
- Initially some re-training of installers on using different ducting materials and duct installation techniques.

Option 2C: Hybrid supply design

The **hybrid supply** option combines elements of the both the traditional perimeter supply and the central supply designs as shown in Figure 7. This supply option may include:

- Interior high-wall outlets on upper floors,
- Perimeter floor outlets on the main floor, and
- Ceiling outlets in basement.

Advantage of the hybrid supply approach may include:

- Reduced duct lengths contributing to reduced ducting costs;
- High wall supply outlets that provide superior cooling on upper floors;
- Supply outlets on walls of upper floors which do not interfere with furniture placement.

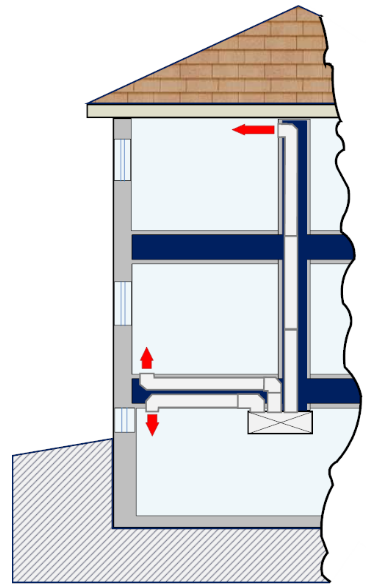


Figure 7: Hybrid supply design

Additional planning for implementing hybrid supply designs may include:

- Some changes to duct design practices commonly used by mechanical designers;
- The use of different ducting materials and/or grille/diffuser types for upper floors; and,
- Initially some re-training of installers on using different ducting materials and duct installation techniques on upper floors.

NOTE TO BUILDERS: STRUCTURAL PLANS

Mechanical designers will need the structural plans for your house model to be able to optimize the design and layout of the supply ducting for the home.

Optimized duct systems use less ducting and contribute to lower ducting costs. This may require some adjustments to floor and wall framing plans.

STEP 3: CHOOSE SUPPLY DUCT VELOCITY / STATIC PRESSURE

The decision on which ducting technology to use:

- *Will effect supply duct sizes and the amount of bulkheads used in the home.*
- *Will also effect the amount of electricity used by the heating equipment.*
- *Can have a bearing on the availability and choices of compatible heating equipment.*

"Low-velocity", *"medium-velocity"* and *"high-velocity"* are common terms used to describe types of ducting technologies which use different static pressures and duct sizes to deliver conditioned supply air to various parts of the house, though the operating static pressure ranges for each type often vary from manufacturer to manufacturer.

For purposes of this guide, the static pressure ranges and typical branch duct diameters used by the three different ducting technologies are defined in Table 3. The ESP values shown do not include the static pressure drop across the cooling coil.

Table 3: Duct technologies and their corresponding external static pressure and branch duct diameter ranges

Duct Technology	Total of Supply and Return Duct External Static Pressure (ESP) at design airflow	Typical supply branch diameter
3A. Low-velocity	Total ESP less than or equal to 0.5 inch water column (WC)	4 to 6 inch
3B. Medium-velocity	Total ESP between 0.5 and 1.0 inch WC	3 to 4 inch
3C. High-velocity	Total ESP greater than 1.0 inch WC	less than 3 inch

Builders are encouraged to consult with their mechanical designers to learn more about the pros and cons of each ducting approach, and together decide which ducting technology is best for a given housing project before the duct design is initiated.

The illustrations are intended to convey the relative air velocity and static pressure in the branch ducts of the different types of duct technologies, and are not necessarily representative of the actual connections of the ducts to the mechanical equipment.

Option 3A: Low-velocity / Low-static-pressure ducting

Low-velocity systems operate with total external static pressures (ESP) of up to 0.5 inch WC, and have been the traditional market-dominant duct technology. An example of a low-velocity system is shown in Figure 8. These types of systems use larger cross-section ducts and their low-static pressure design minimizes blower energy consumption.

From an installation perspective, the larger cross-section ducts can be more challenging to integrate and install in joist and wall cavities. Some corner boxes and bulkheads may be required to conceal some ductwork.

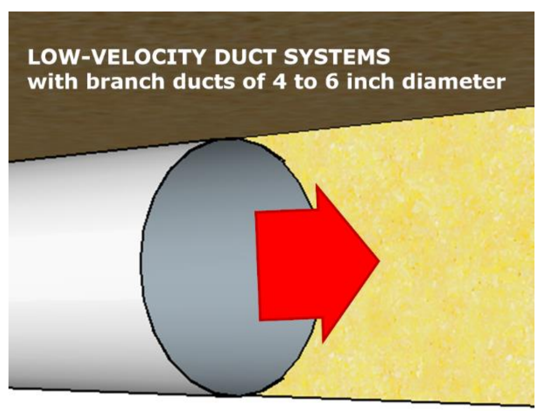


Figure 8: Low-velocity Duct System

Option 3B: Medium-velocity / Medium-static-pressure ducting

Medium-velocity systems, such as the one shown in Figure 9 operate with a total ESP of between 0.5 and 1.0 inch WC and are being used as a “middle-of-the-road” option between low-velocity and high-velocity systems. Medium-velocity systems use medium cross-section ducts which result in medium static-pressures and slightly higher blower energy consumption than low-velocity systems.

From an installation perspective, the medium cross-section ducts are more easily integrated and installed in joist and wall cavities of the home.

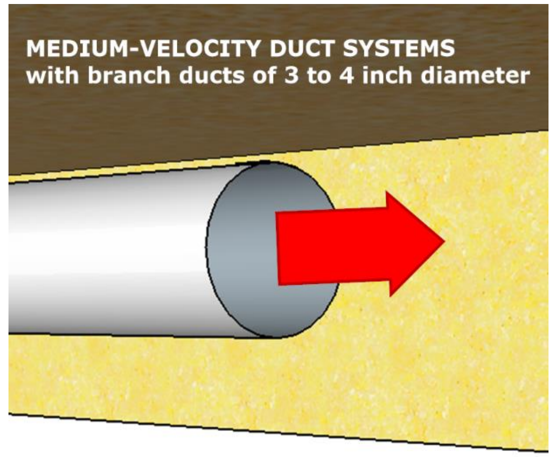


Figure 9: Medium-velocity Duct System

Option 3C: High-velocity / High-static-pressure ducting

High-velocity systems, such as the one shown in Figure 10 operate with a total ESP above 1.0 inch WC and have been used for a number of years especially in the townhome segment. Their small cross-section ducts result in high-static pressures and higher blower energy consumption than both low-velocity and medium-velocity systems. High-velocity duct systems often use proprietary designs and may include approaches for muffling sounds associated with high-velocity airflows.

From an installation perspective, the small cross-section ducts are more easily installed inside joist and wall cavities of the home.

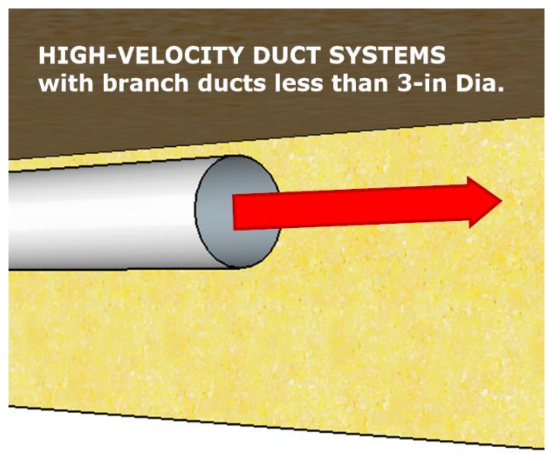


Figure 10: High-velocity Duct System

STEP 4: CHOOSE SUPPLY DUCT ZONING

Houses with multiple floors, or distinctly different occupancy patterns on a single floor, may benefit from supply ducting that is divided into a number of separate supply zones, each controlled by an individual zone thermostat. Zoning of supply ducting can provide:

- *Enhanced occupant comfort which will help minimize call backs, and*
- *Additional energy and peak demand control to help homebuyers manage their usage.*

Choose the number and arrangement of supply zones to satisfy both comfort and energy management considerations for your house type.

Option 4A: Single-zone supply ducting

In this traditional approach, the whole house is treated as a single zone and is supplied by a single supply duct system. Temperature is controlled by a single thermostat normally located on the main floor of the house. Single-zone systems may provide comfort in house designs with fewer floors which have rooms and areas with similar heating and cooling needs throughout the year.

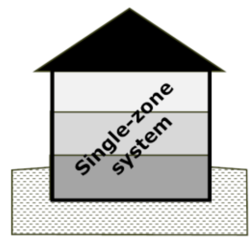


Figure 11: Example of a Single-zone system

Option 4B: Assign one zone per floor

In multi-floor house designs, assigning one zone per floor provides individual floor comfort control and flexibility for energy savings when specific floors are unoccupied by using zone temperature setbacks.

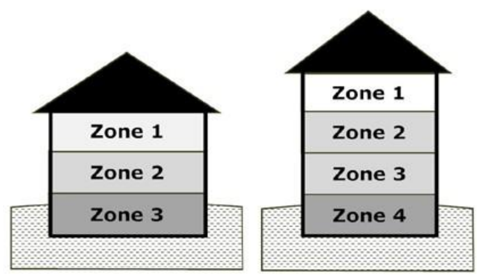


Figure 12: Examples of assigning one zone per floor

Option 4C: Other zoning approaches

Other zoning approaches include:

- Grouping some floors into a single zone, and
- Dividing single floors into multiple zones.

Grouping some floors into a single zone may help reduce builder costs while maintaining flexibility for comfort control and opportunities for energy savings using zone temperature setbacks.

Uppermost floors, including lofts, are a distinct zone as hot air tends to pool at the top of the house.

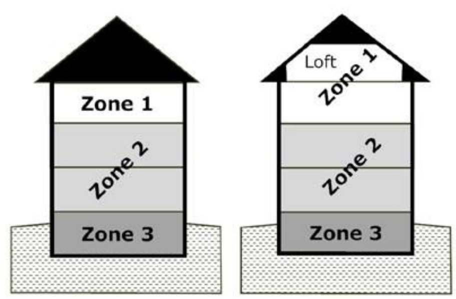


Figure 13: Examples of small footprint homes with some floors grouped into a single zone

- Zoning upper floors will:
  - Improve sleeping conditions at night.
  - Reduce tendency to oversize A/C units to compensate for inadequate cooling on upper floors, and
  - Allow use of daytime setback to reduce peak electricity usage during summer heat waves while maintaining comfort in the main living areas.

Intermediate floors may have similar heating and cooling loads to each other, and can be grouped into a single zone and controlled by a single thermostat.

- Grouping intermediate floors can help balance the size of the heating loads from zone to zone, which may impact equipment choices.

Basements are a distinct zone. They are at the bottom of the house where colder air is most likely to pool, and heat loss and gains are more affected by seasonal soil temperatures than daily weather.

- Zoning can be used to reduce the overcooling of basements during the summer and provide winter warmth when basements are occupied.

Dividing single floors into multiple zones may be used for larger footprint homes, such as single-storey bungalows, with distinctly different heating and cooling loads and occupancy patterns on a single floor. Figure 14 shows an example bungalow floor plan with three zones assigned to different areas of the home.

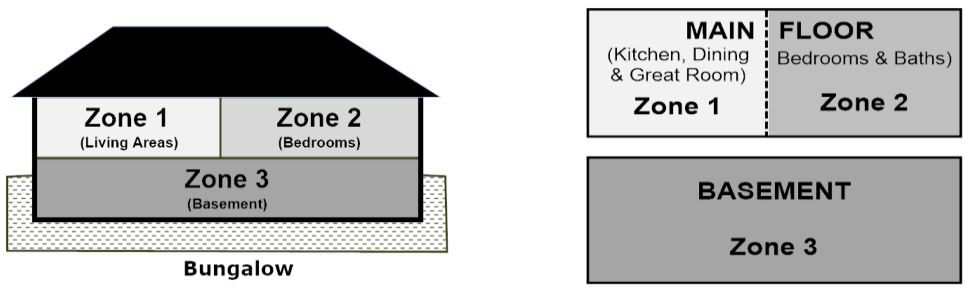


Figure 14: Example of a single-storey bungalow with two separate zones on the main floor

In all cases, the builder is advised to consult a duct design professional in order to confirm the appropriateness of the proposed zoning approach based upon: room by room heat loss and gain calculation results, the related implications on comfort and energy needs, and compatibility with the heating and cooling equipment selected.

Additional References:

1. **Zoning Decision Guide for Builders**, Natural Resources Canada publication, 2015. PDF available on-line at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/LEEP_Zoning_Guide_for_Builders_e.pdf
2. **Zoning Duct Design Guide**, Natural Resources Canada publication, 2017. PDF available on-line at: http://www.nrcan.gc.ca/energy/efficiency/housing/research/20277

STEP 5: CHOOSE EQUIPMENT ZONING

Houses with zoned duct systems may benefit from fully zoned systems that deliver conditioned supply air to separate areas of the house, each controlled by an individual zone thermostat. Zoned equipment installations can provide:

- *Enhanced occupant comfort which will help minimize call backs, and*
- *Additional energy and peak demand control to help homebuyers manage their usage.*

Choose the type of equipment zoning installation that is compatible with the supply duct zoning chosen in STEP 4, and to satisfy both comfort and energy management considerations for your house type.

Option 5A: Non-Zoned Installation

In this traditional installation, non-zoned HVAC equipment is used with a single-zone supply duct system. An example of a non-zoned installation is shown in Figure 15.

In this type of installation, all areas of the home receive conditioned air simultaneously based on the control of a single thermostat that is usually located in the main living area.

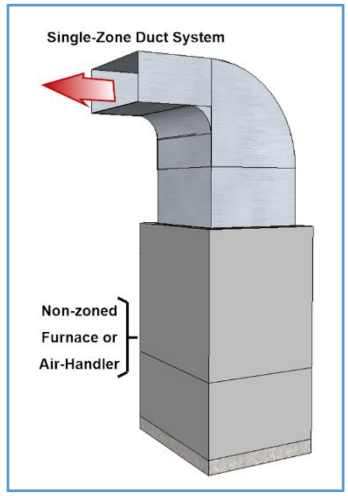
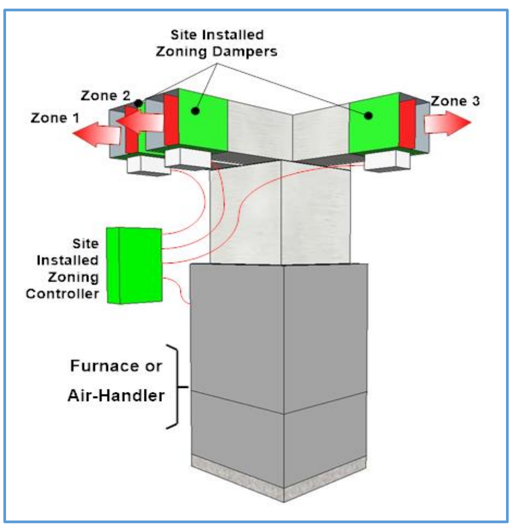


Figure 15: Non-Zoned Installation

Option 5B: Zoned Installation

In this installation option, zoned HVAC equipment is used with a zoned supply duct system that has multiple supply trunks connect to different areas or zones in the home. Examples of zoned equipment Installations are shown in Figure 16.



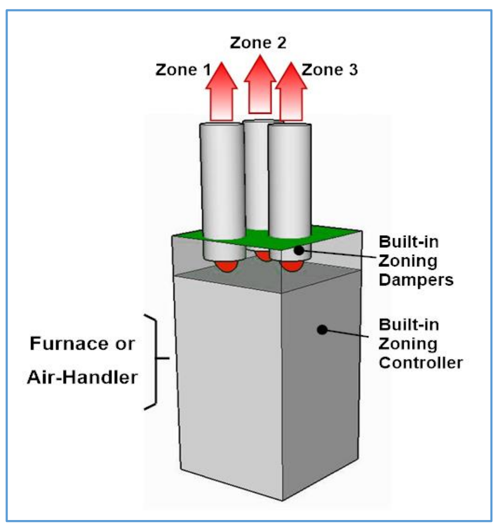


Figure 16: Zoned Installations: a) Site-installed zoning; b) Factory-integrated zoning

Depending on the equipment manufacturer, zoned equipment can be either:

- Site-assembled from multiple components, or
- Delivered to site as a factory-integrated, zoned heating appliance.

In either case, automatic zoning dampers independently control the delivery of conditioned supply air to the different zones within the home under the control of individual thermostats located in each of the zones.

A zoned installation will:

- Enhance comfort by independently controlling the temperature of the different zones within the home, and
- Provide homebuyers with additional flexibility for energy savings by using zone temperature setbacks.

Option 5C: Zoned-Ready Installation

In this installation option, non-zone HVAC equipment, controlled by a single main floor thermostat, is installed with a zoned duct system. An example of a Zone-Ready installation is shown in Figure 17.

The Zoned-Ready installation will:

- Improve system airflow effectiveness, helping conditioned air get to where it's intended to go, even when used in combination with traditional non-zone HVAC equipment.
- Enable zoned equipment with automatic zoning dampers to be installed at a later date.

As an additional comfort-related option, Zone-Ready Installations may be fitted with a manual damper on the supply trunk connected to the basement zone. This optional manual damper can be used seasonally to adjust the flow of conditioned air to the basement to maximize comfort conditions during both the winter heating and summer cooling seasons.

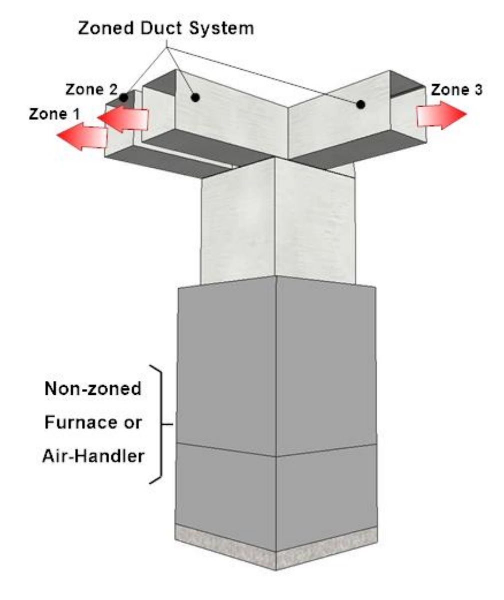


Figure 17: Zone-Ready Installation

Additional References:

1. **Zoning Decision Guide for Builders**, Natural Resources Canada publication, 2015. PDF available on-line at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/LEEP_Zoning_Guide_for_Builders_e.pdf
2. **Zoning Duct Design Guide**, Natural Resources Canada publication, 2017. PDF available on-line at: http://www.nrcan.gc.ca/energy/efficiency/housing/research/20277

STEP 6: CHOOSE RETURN INLET PLACEMENT

The type of return air system can*:*

- *Impact the effectiveness of air circulation and occupant comfort, and*
- *Effect the installed cost of return ducting in the home.*

Choose the type of return air system to be installed in your house.

Option 6A: Traditional return system

This is a "*no change from current practice"* option which typically uses:

- Multiple air-return inlets on each floor.
- Return locations determined by a duct design procedure such as *HRAI's Residential Air System Design (RASD) Manual for Air Heating/Cooling Systems* or equivalent.

An example of the traditional return inlet layout in a two-storey house, installed using the joist-to trunk return installation method is shown in Figure 18.

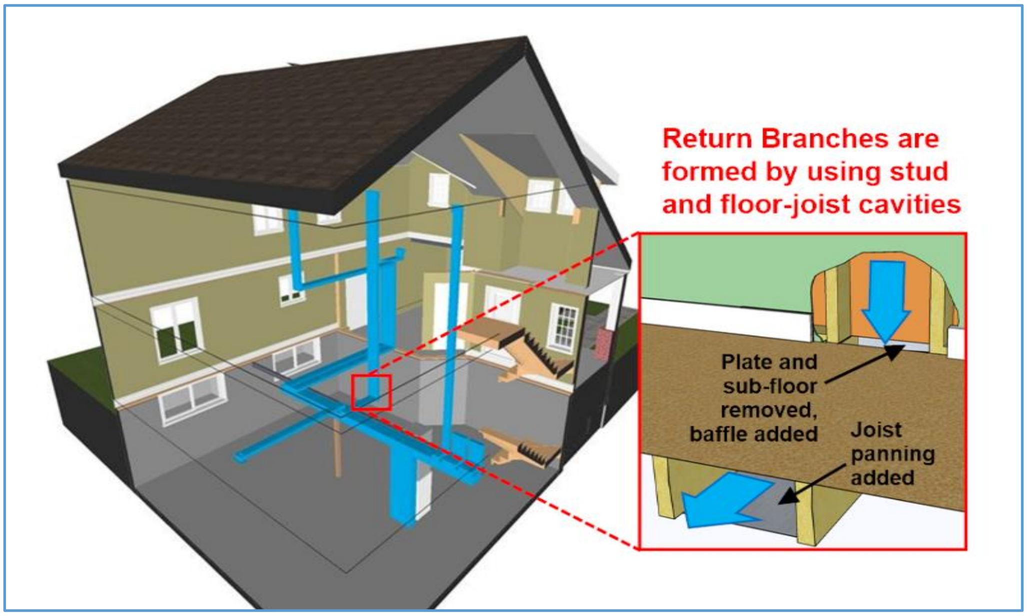


Figure 18: Example of a Traditional Return Duct System in a Two-Storey House

Option 6B: Simplified return system

This return ducting option is:

- Effective in multi-storey home designs.
- Uses a simplified design which may reduce installation costs and enhance air-distribution system effectiveness.
- Best practice application uses the “hard-ducted” return installation method.

The procedure for locating return-air inlets using the **Simplified Return Inlet Layout** is:

- Locate one return-air inlet centrally in the basement at floor level and connect it to the return trunk in close proximity to the equipment.
- Locate another return-air inlet at the highest point in the home which is central and open to other levels/floors (e.g. upper floor central hallway).
- In any rooms with un-heated space below (e.g., rooms over garages, porches, etc.), the designer should locate a low-wall, baseboard or preferably a floor return in the room. It should be placed as far as practical from the supply outlet located in the room and hard piped /ducted back to the return trunk.
- If there is no airflow separation between the main and upper floors, the designer may consider omitting a return for the main floor, unless required by local code authorities.
- If an HRV is connected to the return air trunk, the designer should treat is as a return air inlet.
- The grilles and duct branches must be sized to return the full volume of equipment design airflow (i.e. cubic feet per minute or cfm).

An example of the **simplified return inlet layout** in a two-storey house, installed using the **hard-ducted return installation** method is shown in Figure 19.

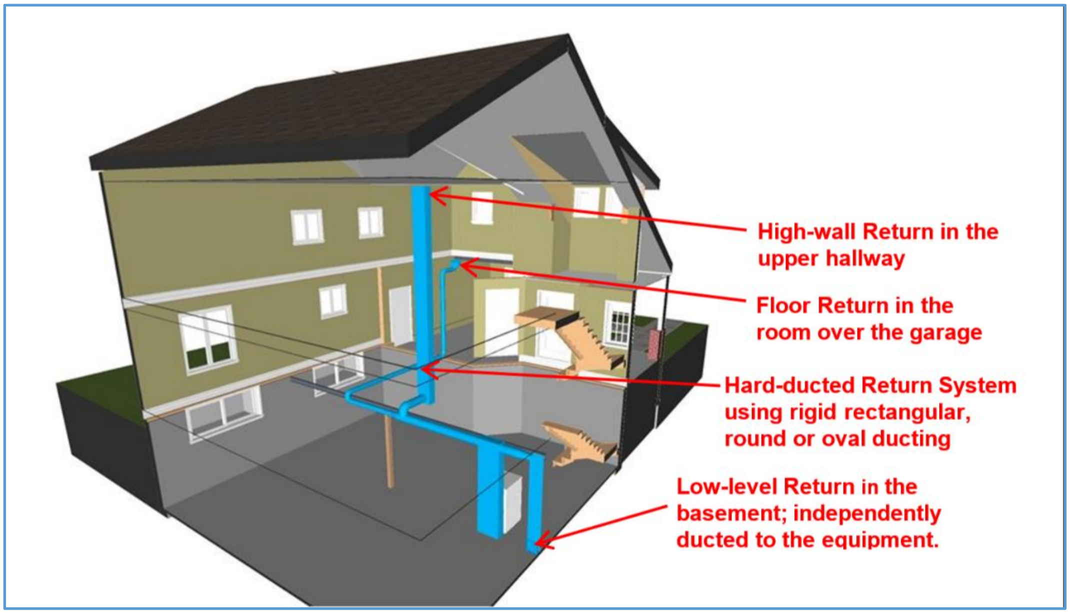


Figure 19: Example of a Simplified Return Duct System in a Two-Storey House

DESIGN NOTE: Simplified Return

When using a simplified return duct system, builders and mechanical designers should plan for and specify appropriate design changes to allow return air to exit bedrooms with closed doors that do not have return inlets. Depending on the airflow requirements of the room, design changes may be required:

- Greater undercutting doors, or
- Providing transfer grilles between the rooms and hallway.

These design changes may increase sound transmission to and from the rooms affected.

NOTE TO BUILDER: STRUCTURAL PLANS

Mechanical designers will need the structural plans for your house model to be able to optimize the design and layout of the return ducting for the home.

Optimized duct systems use less ducting and contribute to lower ducting costs. This may require some adjustments to floor and wall framing plans.

STEP 7: CHOOSE THE DUCT SEALING LEVEL

Sealing ductwork is important to:

- *Ensure conditioned air is distributed as designed to meet loads at design conditions,*
- *Provide more even temperature and comfort throughout the home, and*
- *Reduce customer complaints and call backs due to comfort issues.*

In this step, select the level of duct sealing to be applied to the HVAC ductwork.

Option 7A: Base-level sealing

Option A requires:

- For supply ducting installed in conditioned space, sealing supply ducts to SMACNA Class C seal level which includes transverse joints, branch take-offs, and branch supply joints using tape, mastic or gaskets approved for the application as shown in Figure 20.
- For supply and return ducting installed in unconditioned space or outdoors (not shown), sealing all joints and seams to SMACNA Class A seal level, including transverse joints, branch take-offs, longitudinal seams and all applicable duct penetrations using tapes, mastics or gaskets approved for the application.

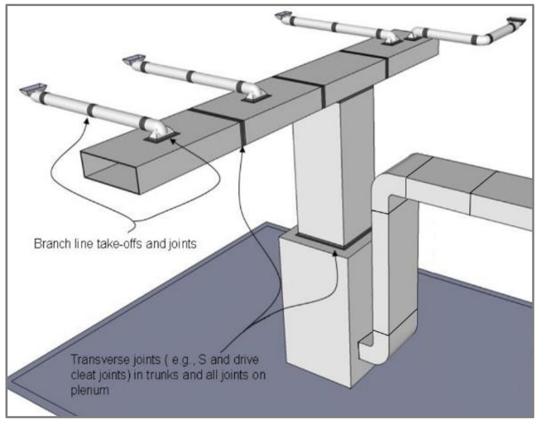


Figure 20: Option 7A duct sealing requirements for supply ducts installed in conditioned space

(Drawing adapted from Natural Resources Canada's ENERGY STAR for New Homes Standard)

Option 7A duct sealing is required by the Ontario Building Code and is considered "best practice" in other regions of the country for new residential construction.

Option B: Sealing to ENERGY STAR for New Home requirements

Figure 21 illustrates the Option 7B duct sealing requirements. This option requires:

- Sealing all supply trunk transverse joints, branch take-offs, branch supply joints and manufactured beaded joints on round perimeter pipes located on all floors using tape, mastic or gaskets approved for the application.
- Seal common return ducts, by applying the more stringent of either (1) or (2):
  (1) The return drop and at least one horizontal metre of return duct(s) measured from the furnace/air

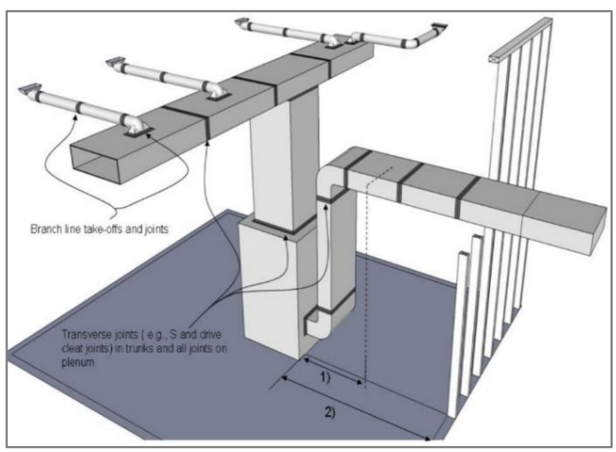


Figure 21: Option 7B duct sealing requirements

(Drawing sourced from Natural Resources Canada's ENERGY STAR for New Homes Standard)

handler connection must be sealed with tape or mastic approved for the application; or

(2) Within a framed or closed mechanical room, all the return ducts, including joist returns, must be sealed with tape or mastic approved for the application.

Option 7B duct sealing is required by the ***ENERGY STAR for New Homes (ESNH) Standard***. The ***ESNH Standard*** also requires that all ducting be installed within the conditioned space.

Option 7C: Sealing to ENERGY STAR for New Home requirements with verification testing

This is a top-level sealing option, which involves:

- Sealing of supply and return ductwork as described in OPTION 7B and illustrated in Figure 21; and,
- Leakage testing of supply ducts to verify that duct leakage levels fall at or below the requirements set by the builder.

Duct leakage is normally measure with the duct system pressurized to 0.1 in WC (25 Pa), and leakage limits can be set as either:

- A percentage of system flowrate, or
- A percentage of above grade floor area, measured in square-feet (sq-ft).

Suggested targets for supply duct leakage at 0.1 in WC (25 Pa) pressurization are:

- Not more than 10% of system flowrate, or
- Not more than 6% of above grade floor area (in sq-ft) as a CFM leakage limit.

For example, a 1,400 sq-ft house with a HVAC flowrate of 800 CFM could have leakage limits set as either:

- Based on system flowrate: 800 CFM x 10% = 80 CFM leakage limit
- Based on floor area: 1,400 sq-ft x 6% (CFM/sq-ft) = 84 CFM leakage limit

Practical Considerations:

Leakage limits based on floor area are easy to establish and use in practice and may have fewer variables than leakage limits based on system flowrate.

Leakage limits based on actual system flowrates require measuring the system flowrate which is complicated by the following practical considerations:

- Some systems can have different flowrates for heating and cooling, which necessitates negotiating which one will be used to as the benchmark for setting leakage limits;
- By necessity, duct leakage testing is done before drywall installation, to enable sealing of detected leaks, and before supply grilles are installed. Under these conditions it is not possible to measure the final system flowrate and accurately establish the benchmark for setting the duct leakage limit;

- Moreover, it is possible the HVAC technician will change the fan motor speed settings upon set up, which will change the final system flowrate after the duct leakage testing has been completed.

One practical alternative is to reference the leakage limit to a design flowrate specified for the HVAC system rather than a system flowrate measurement.

NOTE TO BUILDER: DUCT LEAKAGE TESTING

Builders specifying **Option 7C: Duct Sealing with verification testing** should plan for one of the following approaches.

1. If using **paint-on mastic / taping methods**, plan work flow to allow duct leakage testing of the installed duct system before wall board installation is undertaken to allow access to ducts for any necessary repairs. Testing involves:
   a) Pressurizing ducts with a special testing device commonly referred to as a "Duct Blaster®";
   b) Measuring duct leakage and comparing to predetermined allowable leakage rates;
   c) Identifying and resealing "trouble" joints if the measured leakage rate exceeds the allowable duct leakage specification.

2. Use an **internal sealing and testing method** that can take place after wall board installation has been completed. This sealing method involves:
   a) Covering all supply registers in order for air to escape only through the leaks;
   b) Injecting and circulating "sticky-dust" sealant particles throughout the duct system using special equipment;
   c) Small sealant particles adhering to the edges of leaks as they exit the system and gradually sealing any small gaps in the duct system;
   d) Issuing a "certificate of completion" to provide verification of the sealing process.

STEP 8: PREREQUISITE LOAD CALCULATIONS

While working with Canadian builders, the LEEP team has seen space heating equipment being quoted that is 2 to 4 times the calculated design heat loss (DHL) of the house.

Sizing can impact first cost and customer comfort. The National Building Code requires that the capacity of heating appliances be determined in accordance with CSA F280.

In this prerequisite step, the builder should work with their mechanical designer to:

- Determine the Design Heat Loss (DHL) and the Design Heat Gain (DHG) for the specific house model using design climate data for the building site;
- Calculate the ventilation requirements for the home; and,
- Estimate the peak domestic hot water (DHW) capacity requirements for the home.

Gather house plans and detailed envelope specifications

The builder should provide a complete set of construction schematics and other specifications to their mechanical designer for the particular house model being considered as input to the load calculations and the HVAC system design processes. Areas of particular interest include:

- House air tightness levels and window specifications (e.g. design factors that will influence heating and cooling loads, and impact equipment and duct sizing);
- Front door orientation (e.g. information that will impact cooling loads and equipment sizing);
- Joist plan details (e.g. information needed to minimizes ductwork elbows and equivalent lengths);
- Heating equipment location (e.g. information needed to specify supply trunk locations).

Determine the F280-12 Design Heat Loss and Heat Gain Values

Some items for builders to consider are:

- Carrying out CSA F280-12 heat loss/gain analysis enables right sizing heating and cooling systems to improve comfort, reduces build cost, and lowers your risk of call backs.
- When completing CSA F280-12 analyses, it is fast and cost effective to considering upgrade options that can further reduce the size of your mechanical systems.
- Providing standardized and comprehensive performance details when submitting your house plans for analysis will help to ensure you get the best results.
- Reviewing the heat loss/gain results helps ensure the results are right and lets you see where you may want to focus attention during your next builds.
- Make sure your heat loss/gain professional is accredited, experienced and uses software that has been developed to conform to the CSA F280-12 standard.

The mechanical designer should use their normal methodology for completing DHL and DHG calculations, and review the results with the builder.

Examples of Design Heating Loads for a two-story single detached house

Design space heating loads are much lower than in yesteryear as a result of trends towards using more and continuous insulation, better air sealing and better windows. The chart in Figure 22 illustrates the design heat loss (DHL) values for a 1,400 ft^2, two-storey, detached house located in four cities across Canada, and constructed to three different levels of home energy performance.

The four cities with their respective design conditions are:

- **Greater Toronto Area (e.g. Vaughan/Woodbridge, ON)**
  - Heating: -4°F (-20°C), and
  - Cooling: 88°F (31°C) with a humidity ratio of 112 gr/lb (16 g/kg).
- **Ottawa, ON**
  - Heating: -13°F (-25°C), and
  - Cooling: 86°F (30°C) with a humidity ratio of 105 gr/lb (15 g/kg).
- **Calgary, AB**
  - Heating: -22°F (-30°C), and
  - Cooling: 82°F (28°C) with a humidity ratio of 56 gr/lb (8 g/kg).
- **Saskatoon, SK**
  - Heating: -31°F (-35°C), and
  - Cooling: 86°F (30°C) with a humidity ratio of 84 gr/lb (12 g/kg).

The three levels of home energy performance are:

- **Basic house**, constructed to local Building Code requirements;
- **ENSH house**, constructed to ENERGY STAR for New Homes Standard (ESNH version 12.8 and 17.0 Ontario); and,
- **R-2000 house**, constructed to R-2000 Standard (Version that came into effect July 1, 2012).

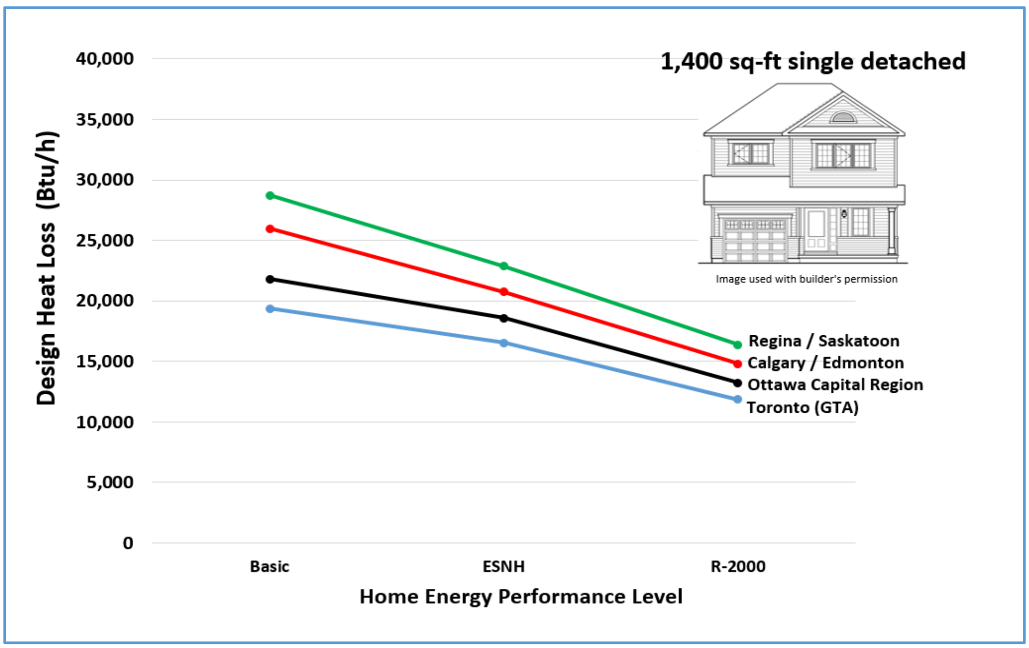


Figure 22: Design Heat Loss values for a single, detached house in four Canadian Cities

The DHL values for the Basic house range from about 20,000 to 29,000 Btu/h depending on the city location.

The more energy efficient house designs have even lower DHL values:

- The ESNH house has design heating loads in the four cities ranging from about 17,000 Btu/h to 23,000 Btu/h; and,
- The R-2000 house has design heating loads of 12,000 to 17,000 Btu/h.

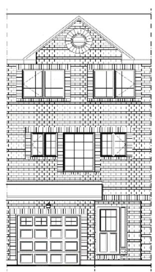
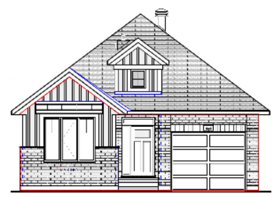
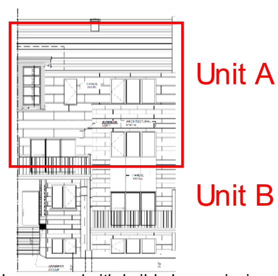
Design Loads for Other Housing Types

Table 4 compares design heating and cooling loads for four different housing types:

- A three-storey town,
- A two-storey single detached (also shown in the previous figure),
- A one-story single detached, and
- A two-storey back-to back town.

Each of these example houses is constructed to ENERGY STAR for New Homes Standard (ESNH version 12.8 and 17.0 Ontario) and located in the four previously mentioned cities.

Table 4: Examples of CSA F280-12 design heat loss and gain values for different housing types in four Canadian cities

Three-storey, town	Two-storey, single, detached	One-storey, single, detached	Two-storey, stacked back-to-back town
 Image used with builder's permission	 Image used with builder's permission	 Image used with builder's permission	 Image used with builder's permission
Description: • 1,600 sf on 3 floors plus basement • Front facing E (highest cooling) • ESNH certified	**Description:** • 1,400 sf on 2 floors plus basement • Front facing W (highest cooling) • ESNH certified	**Description:** • 1,300 sf bungalow plus basement • Front facing NW (highest cooling) • ESNH certified	**Description:** • 1,100 sf on 2 floors • Front facing SW (highest cooling); Units A & B share an entrance • ESNH certified
Design Loads: (for mid unit)	**Design Loads:**	**Design Loads:**	**Design Loads:** (for upper-mid unit)
Greater Toronto Area, ON DHL: 15,786 Btu/h DHG: 19,192 Btu/h	**Greater Toronto Area, ON** DHL: 16,547 Btu/h DHG: 18,556 Btu/h	**Greater Toronto Area, ON** DHL: 20,335 Btu/h DHG: 19,354 Btu/h	**Greater Toronto Area, ON** DHL: 6,901 Btu/h DHG: 13,850 Btu/h
Ottawa, ON DHL: 17,721 Btu/h DHG: 18,807 Btu/h	**Ottawa, ON** DHL: 18,573 Btu/h DHG: 18,147 Btu/h	**Ottawa, ON** DHL: 22,862 Btu/h DHG: 18,655 Btu/h	**Ottawa, ON** DHL: 7,984 Btu/h DHG: 14,067 Btu/h
Calgary, AB DHL: 19,817 Btu/h DHG: 18,118 Btu/h	**Calgary, AB** DHL: 20,738 Btu/h DHG: 17,375 Btu/h	**Calgary, AB** DHL: 25,601 DHG: 18,851 Btu/h	**Calgary, AB** DHL: 8,775 Btu/h DHG: 14,468 Btu/h
Saskatoon, SK DHL: 21,991 Btu/h DHG: 18,822 Btu/h	**Saskatoon, SK** DHL: 22,879 Btu/h DHG: 18,169 Btu/h	**Saskatoon, SK** DHL: 28,249 Btu/h DHG: 19,899 Btu/h	**Saskatoon, SK** DHL: 9,779 Btu/h DHG: 14,841 Btu/h

Notes:
1. Design Heat Loss and Heat Gain values were calculated using Wrightsoft® Right-Suite® Universal 2017 design software.

The first three house types have DHL values that are below 30,000 Btu/h in all four cities when constructed to ESNH requirements. The stacked back-to-back townhouse has DHL values of less than 10,000 Btu/h in all four cities when constructed to ESNH requirements.

Design cooling loads vary less from location to location. Design heat gain (DHG) values for the first three house types are about 20,000 Btu/h, while the stacked back-to-back townhouse has DHG values of about 15,000 Btu/h in all four cities.

Determine the Ventilation Requirements for the Home

The mechanical designer should calculate the ventilation capacity requirements for the home using their normal methodology that is compliant with their provincial Building Code.

Determine the Domestic Hot Water Capacity Requirements

The mechanical designer should calculate the peak domestic hot water (DHW) capacity requirements for the house use their normal methodology for determining peak hot water usage. This peak DHW heating requirement can then be compared to equipment ratings when selecting either an on-demand or storage-tank water heater for the home.

Capacity Ratings of On-Demand Water Heaters

For installations using on-demand water heaters it may be necessary to consider the minimum cold water inlet temperature at the build location when specifying the minimum DHW capacity of the equipment as the cold water inlet temperature will impact the actual DHW delivery capacity at the build site.

Table 5 provides some examples of how inlet cold water temperature impacts required DHW capacity ratings for inlet water temperatures of 5, 10 and 15°C.

Table 5: Impact of inlet water temperature on required capacity ratings of On-Demand Water Heaters

Required Peak DHW Capacity	Minimum wintertime inlet water temperature	Minimum required on-demand water heater capacity rating	Equivalent minimum required One-Hour Rating (OHR)
15 L/min	15ºC	14.7 L/min	882 L
15 L/min	10ºC	16.9 L/min	1,014 L
15 L/min	5ºC	19.1 L/min	1,146 L

Capacity Ratings of Storage-Tank Water Heaters

For systems using storage tank water heaters, designers may refer to the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI) Skilltech Academy's Worksheets for guidelines on sizing storage tank capacity to meet peak DHW demands.

STEP 9: SIZE COOLING CAPACITY

Sizing air-conditioning (A/C) equipment is important because:

- *It may dictate the peak airflow requirements which impacts duct sizing and ducting costs for the home,*
- *It impacts cooling effectiveness and occupant comfort, which can influence customer satisfaction and call backs due to comfort issues.*

In this decision step you will provisionally size the air-conditioning (A/C) condenser based on the CSA F280-12 design heat gain calculated for your house design at the building-site location.

Guidelines for sizing A/C Condenser Capacity:

HRAI Canada guidelines for selecting air-conditioner condenser capacity is to choose an A/C unit that has a cooling output of 80% to 125% of the total cooling load of the house. An example of this sizing guideline is shown graphically in Figure 23 for A/C condenser sizes from 1 Ton to 2-1/2 Tons of cooling capacity, covering a cooling load range from 9,600 Btu/h to 37,500 Btu/h.

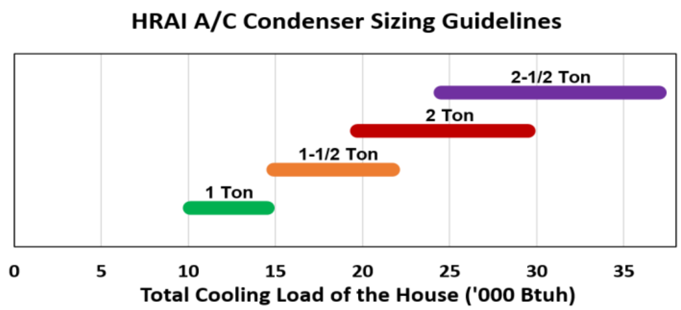


Figure 23: Example of HRAI A/C Condenser Sizing Guidelines

Energy-efficient homes will likely have total cooling loads that are below 30,000 Btu/h, and can be satisfied with A/C condenser sizes of between 1 and 2 Tons. As you can see in the Figure 23, the HRAI recommended ranges overlap. Removing the overlap between different A/C condenser sizes can be done by either favouring larger or smaller A/C condenser sizes as shown in Table 6.

Table 6: Cooling outputs and applicable cooling load ranges in '000 Btu/h for common A/C condenser sizes

Parameter	OPTION 9A *1 Ton A/C Condenser*	OPTION 9B *1-1/2 Ton A/C Condenser*	OPTION 9C *2 Ton or larger A/C Condenser*
Nominal Cooling Capacity ('000 Btu/h)	12	18	24 or higher
HRAI Applicable Cooling Load Range ('000 Btu/h)	9.6 to 15.0	14.4 to 22.5	19.2 or higher
HRAI Load Range with Larger A/C preference ('000 Btu/h)	9.6 to 14.4	14.4 to 19.2	19.2 or higher
HRAI Load Range with Smaller A/C preference ('000 Btu/h)	9.6 to 15.0	15.0 to 22.5	22.5 or higher

Manufacturers' guidelines may vary from the ones provided by HRAI. It is recommended that builders check with their equipment manufacturer for specific A/C sizing guidelines based on the total design heat gain (DHG) calculated for the house.

As an example, following HRAI guidelines for a house with a design heat gain value of 20,500 Btu/h would require either:

- **Option 9B:** 1-1/2 Ton A/C condenser, if sized using the "smaller A/C preference", or
- **Option 9C:** 2-Ton A/C condenser if sized using the "larger A/C preference"

The former A/C choice would require a cooling system airflow of about 600 CFM while the latter would require about 800 CFM, using the rule-of-thumb of 400 CFM per ton of A/C capacity.

In this example case, we will assume the designer chooses **Option 9B: 1-1/2 Ton A/C unit with a cooling airflow of 600 CFM.**

Consequences of Oversizing A/C Capacity

Oversizing A/C capacity has sometimes been perceived as a way to address complaints of poor cooling performance, especially in houses with multiple levels (e.g. 3-storey townhomes). More often, oversizing A/C capacity will create new issues and result in a range of consequences as shown in Table 7.

Table 7: Issues and possible consequences of Oversizing A/C Capacity

Oversized A/C units result in ...	*Possible Consequences*
• **Need for larger equipment and ducting**	• Higher cooling equipment costs; • Larger ducting required to handle higher airflows and associated higher ducting costs; and, • Larger heating equipment may be needed to provide necessary cooling airflow, and associated higher heating equipment costs.
• **Short cooling system runtimes**	• Poor dehumidification performance impacts indoor comfort; • End-of-line rooms not cooled enough.
• **Lower than normal thermostat settings** *(used by the homebuyer to extend cooling-system runtimes)*	• Produces poor comfort conditions that are often described as *"cold and clammy";* • Increases electricity usage and hydro bills.

Design Options for Dealing with Hard-to-Cool Houses

Oversizing A/C capacity beyond HRAI Guidelines should be avoided, and hard-to-cool houses should rather be addressed using one or more of the design options described in Table 8.

Table 8: Design options for improving cooling performance

Design Option	*Guide Information*	*Result*
Reduce Design Cooling Loads by changing Window specifications	**STEP 9** Refer to Figure 24 and Table **9**	Reducing the solar heat gain coefficient (SHGC) of windows will lower cooling loads, and can reduce both A/C capacity requirements and duct sizes which can lower system costs.
Reduce Duct Leakage	**STEP 7,** Option 7A, 7B or 7C	Tighter supply ducts increase the chilled air delivery volume to rooms on upper levels of the home.
Use staged / modulating A/C condensing unit	**STEP 10,** Option 10C	A/C condensing units with two or more stages of cooling capacity can adapt to varying cooling requirements of the home and enhance overall cooling performance.
Zone Supply-Air Ducting and **Equipment Zoning**	**STEP 4,** Options 4B or 4C and **STEP 5** Option 5B	Dividing the house into several separate HVAC zones will improve thermal comfort through the home; separate zone thermostat will seasonally control the delivery of either chilled or heated supply air to different levels or areas of the home as required to maintain comfort conditions.
Improve Supply-Air Duct Performance	**STEP 2,** Options 2B or 2C	High-wall, central supply outlets can enhance cooling performance in upper level rooms.
Improved Return-Air Performance	**STEP 6,** Option 6B	Simplified return design enhance the draw of return air from the upper floors and can improve cooling performance on upper levels of the home.

Impact of Window Selection on Cooling Requirements

Window selection can have a major impact on design cooling loads, which may impact:

- The size of A/C condenser that is installed in the home;
- The size of ducting that is needed to distribute the cooling airflow within the home; and,
- The size circulating fan needed in the heating system to move necessary cooling airflow throughout the home.

Cooling loads are very sensitive to the solar heat gain coefficient (SHGC) of the windows used in the home. Figure 24 illustrates the impact that window choices can have on F280-12 design cooling loads for a three-storey, mid-unit townhome located in southern Ontario.

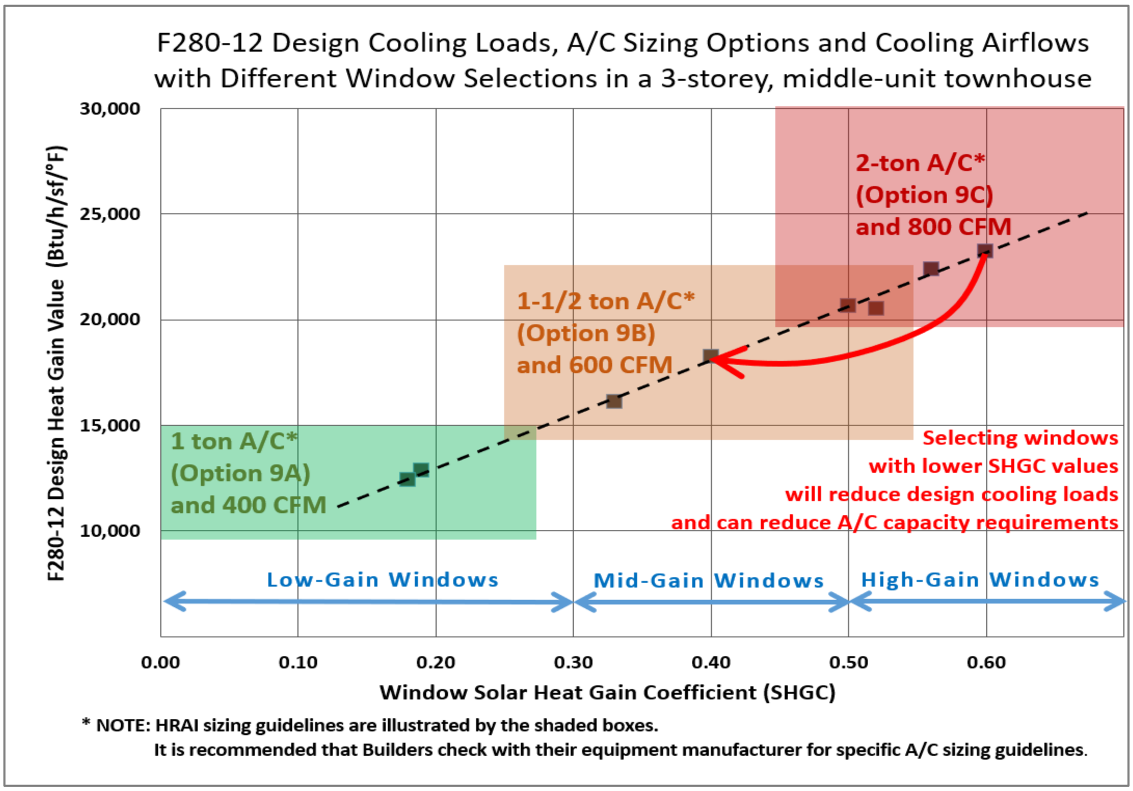


Figure 24: Impact of Window SHGC on Design Cooling Loads for a Townhome

In the example townhome, changing the windows from commonly used “high-gain”, double-glazed units with SHGCs of 0.60 to “mid-gain” double-glazed units with SHGCs of 0.40 would:

- Reduce the design cooling load for the home from 23,000 Btu/h to 18,000 Btu/h
- Reduce the required A/C condenser capacity from 2 tons to 1-1/2 tons, and
- Reduce the required cooling airflow from about 800 CFM to about 600 CFM.

Additional details on the impact of window selection on design loads for the example townhome are provided in Table 9.

Table 9: Impact of Window Parameters on CSA F280-12 Design Loads for a Townhome

No.	Window Description	U-factor (Btu/h/ft²/°F)	USI (W/m²/K)	SHGC	Energy Rating [2]	Design Heat Loss (Btu/h) [3]	Design Heat Gain (Btu/h) [3]
1	Basic, higher-U, High-Gain Double [1]	0.380	2.16	0.56	25	20,040	22,394
2	Basic, common, High-Gain Double [1]	0.350	1.99	0.60	31	19,465	23,248
3	Basic, lower-U, High-Gain Double [1]	0.320	1.82	0.50	29	18,890	20,672
4	Reference High-Gain Double	0.280	1.59	0.52	35	18,123	20,505
5	Reference Low-Gain Double	0.280	1.59	0.19	16	18,123	12,909
6	High-Performance, Mid-Gain Double	0.226	1.28	0.33	31	17,088	16,112
7	High-Performance, Low-Gain Double	0.224	1.27	0.18	23	17,050	12,428

Notes:
1. "Basic" windows have U-factors that are greater than 0.280 Btu/h/ft²/°F and are selected based on Energy Rating (ER) values.
2. The Energy Rating (ER) values shown assumed a window air leakage of zero.
3. Design Heat Loss and Heat Gain values were calculated using Wrightsoft® Right-Suite® Universal 2017 design software.

Cooling versus Heating Loads – Location Matters

The relative size of cooling and heating loads for a house is dependent on the design conditions at the house location. Figure 25 plots the F280-12 design heating and cooling loads for an identical house located in four Canadian cities with different outdoor design conditions.

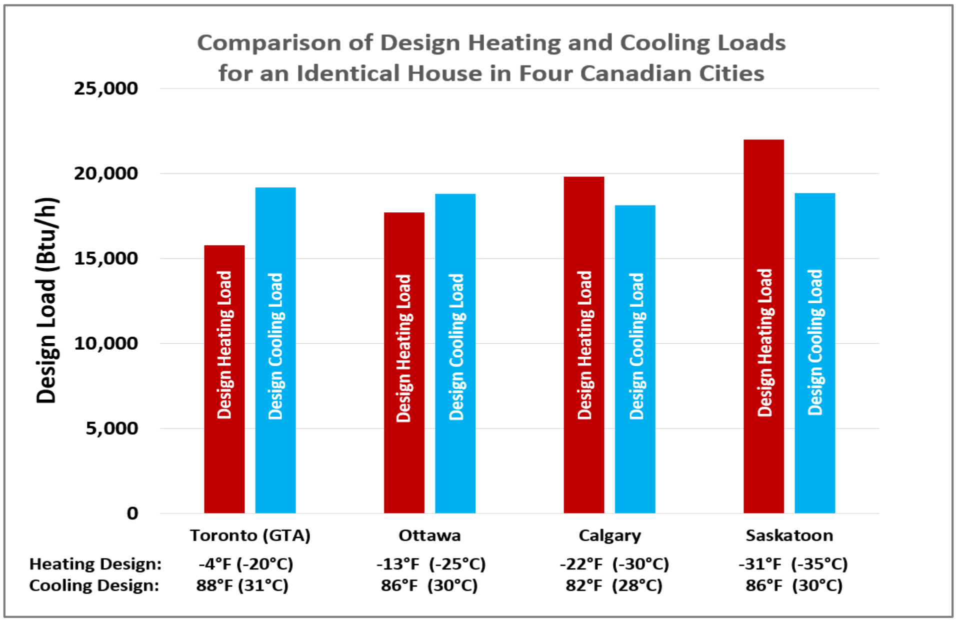


Figure 25: Comparison of Design Heating and Cooling Loads in Four Canadian Cities

As expected, design heating loads vary in a predictable pattern with the lowest loads in Toronto, with a heating design temperature of -4°F (-20°C) and highest in Saskatoon with a heating design temperature of -31°F (-35°C).

Design cooling loads vary much less between the different cities which have cooling design temperatures that are close in value. Peak cooling loads are influenced significantly by solar heat gains through windows and internal loads than solely by outdoor temperature conditions. In this example, all houses had windows with a SHGC of 0.46. Use of windows with a higher SHGC coefficient would increase cooling loads in all cities as illustrated in Figure 24.

STEP 10: CHOOSE DEHUMIDIFICATION STRATEGY AND STAGING / MODULATION – COOLING MODE

Effective dehumidification in regions with high humidity is important to:

- *Ensure summer season comfort throughout the home,*
- *Reduce potential for mold growth, and*
- *Reduce customer complaints and call backs due to comfort issues.*

In this decision step you will choose the type of controls and staging or modulation you require for the air-conditioning (A/C) equipment to be installed in the home.

Option 10A: Single-stage output with no dehumidification strategy

Option 10A represents a basic cooling system installation with a single-stage A/C condenser and circulating fan controls that operate the fan at full cooling speed during a cooling call initiated by the thermostat. Rule-of-thumb airflow rates range from about 360 CFM per ton for humid climate regions to about 400 CFM per ton for drier climate regions.

Dehumidification performance will be affected by the sizing of the A/C condenser relative to the CSA F280-12 Heat Gain values calculated in STEP 2. With this type of cooling system, optimum dehumidification performance will be achieved by not oversizing the A/C condenser which will maximize A/C runtimes while not over cooling the home.

Under this option, oversized cooling systems will short-cycle and provide inadequate dehumidification performance. This can produce cold, damp conditions and results in poor indoor comfort.

Option 10B: Single-stage output with controls that dehumidify before cooling

Option 10B cooling systems use a single-stage A/C condenser with enhanced controls that modify cooling system operation in order to increase the amount of moisture removed from the indoor air before cooling the indoor temperature to the thermostat set-point.

A commonly used strategy reduces the speed of the multi-speed or modulating circulation fan at the start of each cooling call to increase dehumidification performance of the A/C system over a wide range of part-load operating conditions.

Option 10C: Staged or modulated output with controls that dehumidify before cooling

Option 10C cooling systems use an A/C condenser with two or more stages of cooling capacity which can adapt to varying cooling requirements of the home. It is important that cooling controls also alter the circulating fan speed with changes in cooling output in order to maintain good part-load dehumidification performance.

Staged or modulating cooling systems will have longer runtimes than single-stage cooling systems which will enhance indoor comfort during part-load conditions on moderate cooling days.

Zoned HVAC Systems:

Zoned HVAC systems will have wider variation in part-load cooling requirements than single-zone cooling systems due to changes in the number of zones calling for cooling at a particular time.

Staged or modulating (i.e., Option 10C) cooling systems are well positioned to adapt to these widely varying cooling demands and should be considered when installing a zoned HVAC system.

STEP 11: DETERMINE SPACE HEATING SIZE RANGE

Sizing heating equipment is important because:

- *Minimum heating capacity requirements are specified by the Building Code,*
- *It impacts part-load runtimes and heating effectiveness, which can influence customer satisfaction and call backs due to comfort issues.*

In this decision step you will determine the **space heating size range** using:

1. **Option 11A Sizing"** based on F280-12 design heat loss (DHL) calculated in **STEP 8**,
2. **"Best Fit" equipment** from builder's supply chain; **see STEP 13 for additional information.**
3. **Check cooling airflow requirements** based on A/C condenser capacity selected in **STEP 9**.
4. **Heating System Size Ratio** to determine the final space heating size range.

This four-part process is described in Table 10 along with an example.

Determining the Space Heating System Size Range

Table 10: Example of Determining the Space Heating System Size Range

No.	Criteria	Description	Example
1	Option 11A Sizing	Heating equipment output must be sized at 100% or more of F280-12 DHL. Often mechanical designers will add a small safety factor (typically 10% to 25%) to the F280-12 DHL. The size of the factor may vary based on their confidence that the 'as-built' will match the 'as-planned' (related to factors such as air tightness). **This range of 100% to 125% of F280-12 is considered the Option 11A size range** and will provide the longest part-load runtimes with single-stage heating equipment.	**From STEP 8: F280-12 DHL is 15,800 Btu/h** **Option 11A sizing** ranges from 100% to 125% times F280-12 DHL, or ***15,800 Btu/h to 19,750 Btu/h***
2	"Best Fit" Heating Equipment	**Builders and designers are encouraged to select heating equipment within or as close as possible to the "Option 10A size" range** while satisfying other builder requirements (e.g., price, warranty, type or brand of equipment, supplier, etc.). See **STEP 13** for additional information.	For example, the closest sized heating system that is acceptable to the Builder has an output of ***29,000 Btu/h*** If the heating system operates with an airflow of 600 CFM, the temperature rise will be 45°F.
3	Required Airflow for Cooling	The designer will confirm that the selected heating equipment, when operating at the static pressure of the chosen duct system, **will provide the required airflow for the A/C capacity selected in STEP 9.**	**From STEP 9**, the cooling system selected is a **1-1/2 ton** A/C unit, requiring airflow of 600 CFM**.**
4	Heating System Size Ratio	**Heating System Size Ratio** of the selected equipment is: Maximum rated heat output divided by F280-12 DHL times 100%	**Heating System Size Ratio** equals: 29,000 / 15,800 x 100% or ***184% of F280 DHL***

Based on the calculated ***Heating System Size Ratio***, choose one of three space heating size range options.

Option 11A: Between 100% to 125% of F280 design heat loss

- Heating equipment capacity falls within the Option 11A-size range.
- Heating system runtimes with single-stage equipment is defined as **"normal range"** for reference purposes only.
- Two-stage and modulating equipment will extend runtimes to longer than "normal range".

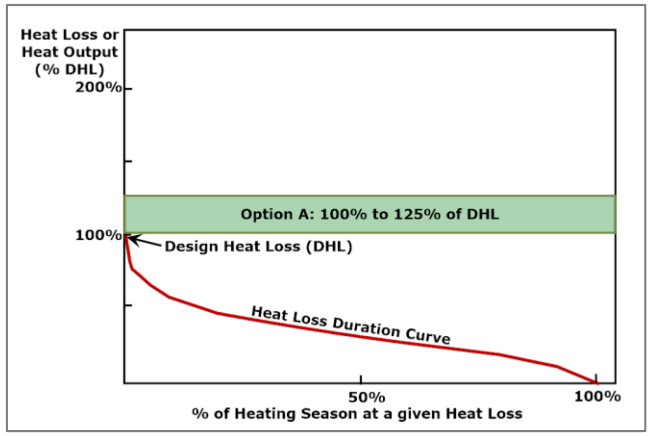


Figure 26: Typical Heat Loss Duration Curve with OPTION 11A heating equipment sizing

Option 11B: Between 126% to 175% of F280 design heat loss

- Option 11B-sized heating equipment is moderately larger than Option 11A-sized equipment.
- Single-stage equipment runtimes will be slightly shorter than "normal range".
- Two-stage equipment will likely extend runtimes into the "normal range",
- Modulating equipment will extend runtimes to longer than "normal range".

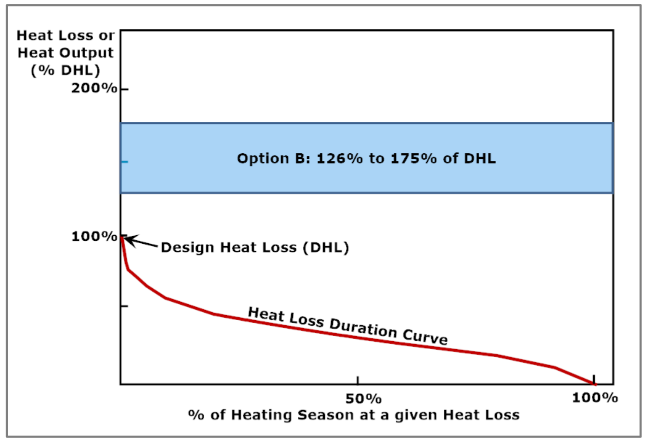


Figure 27: Typical Heat Loss Duration Curve with OPTION 11B heating equipment sizing

Option 11C: Greater than 175% of F280 design heat loss

- Option 11C-sized heating equipment is significantly larger than Option 11A-sized equipment.
- Single-stage system runtimes will be much shorter than "normal range".
- Two-stage equipment will likely approach the "normal range" runtimes.
- Modulating equipment provides the best option for extending runtimes into or above the "normal range".

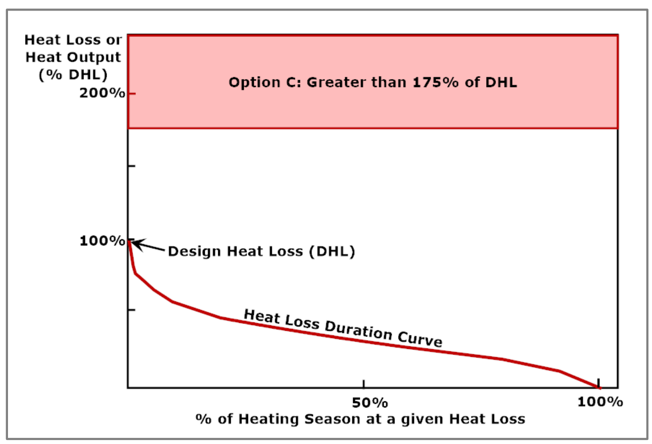


Figure 28: Typical Heat Loss Duration Curve with OPTION 11C heating equipment sizing

The example space heating system in Table 10 has a ***Heating System Size Ratio*** of **184% of F280 design heat loss** which means it would fall into the **Option 11C** size range.

Additional information on typical runtimes for single-stage, two-stage and modulating heating equipment is provided in **STEP 12.**

Design Options for Dealing with Hard-to-Heat Houses

The options in Table 11 provide possible design changes for dealing with hard-to-heat houses.

Table 11: Design options for improving heating performance

Design Option	Guide Information	Result
Reduce Duct Leakage	**STEP 7,** Option 7A, 7B or 7C	Tighter supply ducts increase the heated air delivery volume to rooms on upper levels of the home.
Use staged/modulating Heating equipment	**STEP 12,** Options 12B or 12C	Heating systems with two or more stages of output capacity can adapt to varying heating requirements of the home and enhance overall heating performance.
Zone Supply-Air Ducting and **Equipment Zoning**	**STEP 4,** Options 4B or 4C and **STEP 5** Option 5B	Dividing the house into several separate HVAC zones will improve thermal comfort through the home; separate zone thermostat will seasonally control the delivery of either chilled or heated supply air to different levels or areas of the home as required to maintain comfort conditions.
Improved Return-Air Performance	**STEP 6,** Option 6B	Simplified return design enhance the draw of return air from the upper floors and can improve heating performance on upper levels of the home.

NOTE TO BUILDERS ON THERMOSTAT SETBACKS AND RECOVERY TIMES:

Heating systems sized close to the design heat loss (i.e., ***Option 11A size range***) can take a longer time — as much as one hour — to bring the house back to a comfortable temperature after the thermostat resets to the high temperature setting. **THIS IS NORMAL.**

If homebuyers find that their new home is too cool when they get out of bed or return home from work, ask them to consider:

- Using a smaller temperature setback, or
- Programming the thermostat to start the high temperature setting earlier so the house is at a comfortable temperature when they get out of bed or return from work.

STEP 12: CHOOSE STAGING / MODULATION – HEATING MODE

Choosing the number of heating stages is important because:

- *It impacts part-load runtimes, which can influence customer satisfaction and call backs due to heating comfort issues.*
- *Using two or more stages of output capacity can mitigate short runtimes that occur when there is a large mismatch in heating equipment size compared to design heat loss (DHL) values.*

In this decision step you will choose the number of heat output levels or stages to be specified for the heating equipment (a factor that impacts operating time of the heating system). Heating system runtime, or the length of time that the system is ON in an hour, will vary over the heating season based on:

- The part-load heating demand of the house at the build location,
- The heating system sizing relative to the F280-12 design heat loss (see **STEP 11**), and
- The number of stages / modulation included in the heating equipment.

Longer runtimes are important to ensure comfort conditions by allowing sufficient operating time for temperatures within the ducting system to stabilize and heated air to be delivered to the end-of-line rooms for long enough time before the heating system cycles OFF.

Option 12A: Single-stage heating equipment

Option 12A represents a basic heating system installation with single-stage heating that operates at the same fixed output capacity throughout the heating season.

- This type of equipment cycles OFF and ON at 100% output capacity in order to match the variable heating loads of the house over the heating season.

The **solid line** in Figure 29 shows the typical runtime duration curve for an Option 12A, single-stage heating system that has an output capacity equal to 125% of the design heat loss of the house (i.e., Option 11A size range).

From the chart, during the 5% coldest periods of the heating season, this single-stage heating system will have ON-times that range from around 37 to 48 minutes per hour.

Option 12B: Two-stage heating equipment

Option 12B specifies heating equipment that is designed with a two-stages of output capacity.

- Typically the low-stage heating rate is about 60% of the full-output rating.
- This type of equipment operates on the low-stage output to better match the lower heating loads of homes during most of the heating season, switching to the high-stage output only during the coldest periods or possibly when the heating system is recovering from a temperature setback period.

The **dashed line** in Figure 29 shows the typical runtime duration curve for an Option 12B, two-stage heating system that has an output capacity equal to 125% of the design heat loss of the house (i.e., Option 11A size range).

From the chart, during the 5% coldest periods of the heating season, this size of two-stage heating system will have ON-times that range from around 54 to 60 minutes per hour.

Option 12C: Modulating heating equipment

Option 12C specifies heating equipment that is designed with modulating capacity consisting of three or more stages of heating output.

- Typically the low-stage heating rate is about 40% of the full-output rating, and there will be one or more intermediate stages of heating between this and the 100% output rating.
- This type of equipment operates on the low or intermediate output stages to best match the lower heating loads of homes during most of the heating season, switching to the 100% output stage only occasionally during the coldest periods or possibly when the heating system is recovering from a temperature setback period.

The **dash-dot line** in Figure 29 shows the typical runtime duration curve for an Option 12C, modulating heating system that has an output capacity equal to 125% of the design heat loss of the house (i.e., Option 11A size range).

From the chart, during the 5% coldest periods of the heating season, this modulating heating system will have ON-times that range from around 56 to 60 minutes per hour.

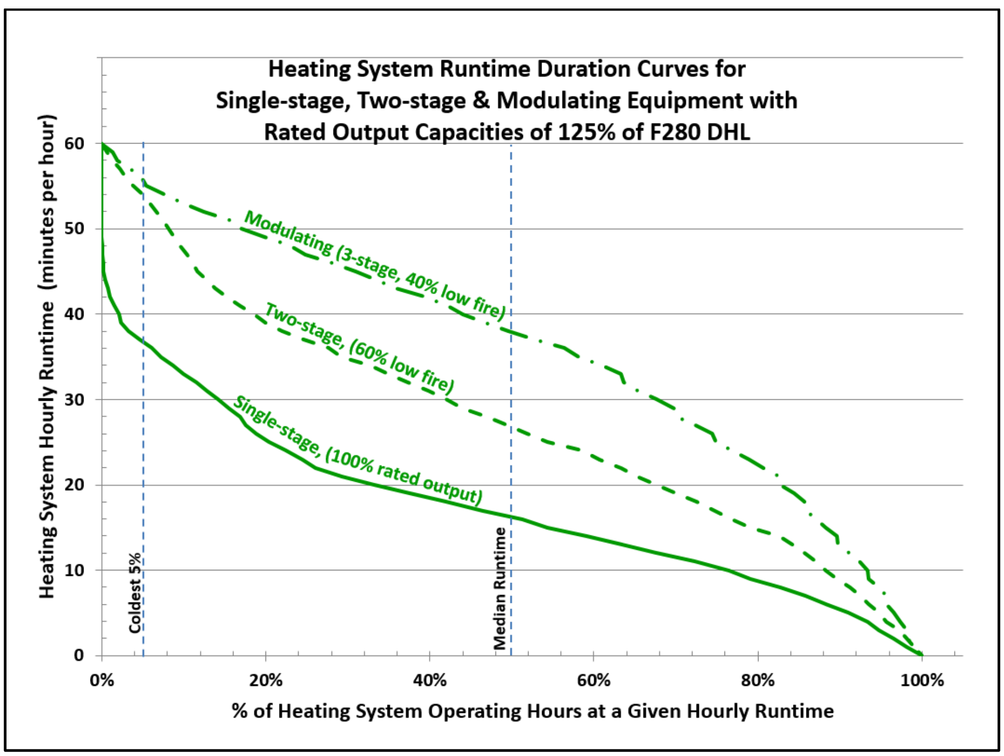


Figure 29: Heating System Runtime Duration Curves for Single-stage, Two-stage and Modulating Systems with rated output capacities of 125% of the Design Heating Loss (DHL)

Median and the 5% coldest-period ON-times are summarized in Table 12 for single-stage, two-stage and modulating heating systems that have rated maximum outputs of 125% of the design heat loss of the house (i.e., Option 11A size range).

Table 12: Median and Coldest 5% Hourly ON-times for Single-stage, Two-Stage and Modulating Heating Systems with rated output capacities of 125% of the Design Heat Loss (DHL)

Parameter	Option 12A: Single-stage	Option 12B: Two-stage	Option 12C: Modulating
Median ON-times	16 minutes per hour	27 minutes per hour	38 minutes per hour
Coldest 5% ON-times	37 minutes per hour	54 minutes per hour	56 minutes per hour
Coldest 5% OFF-times	23 minutes per hour	6 minutes per hours	4 minutes per hour

Single-stage equipment has the shortest ON-times while modulating equipment has the longest ON-times, with two-stage equipment falling between these two extremes.

Runtimes for heating equipment oversized further away from the design heat loss value (i.e., equipment in the Option 11B or Option 11C size ranges) will have shorter ON-times than shown in Table 12. The more oversized heating equipment is, the greater the need for staging or modulation in order to extend the runtimes throughout the heating season.

Zoned HVAC Systems:

Zoned HVAC systems will have wider variation in part-load heating requirements than single-zone heating systems due to changes in the number of zones calling for heating at a particular time.

Two-staged (i.e., Option 12B) or modulating (i.e., Option 12C) heating systems are better positioned to adapt to these widely varying heating demands and should be considered when installing a zoned HVAC system.

NOTE TO BUILDERS ON HOURLY RUNTIMES:

The **runtimes** shown in the chart and table are aggregated for each hour and are not actual cycle times of the heating equipment. Hourly runtime values can consist of more than one heating cycle per hour.

For example, a **runtime of 20 minutes per hour** could consist of:

- 5 minutes ON and 10 minutes OFF, repeated 4 times per hour,
- 10 minutes ON and 20 minutes OFF, repeated twice per hour, or
- Some other combination of ON and OFF times that total to 20 minutes of "ON time" in the hour.

NOTE TO BUILDERS ON THERMOSTAT SETBACKS AND RECOVERY TIMES:

Heating systems sized close to the design heat loss (i.e., ***"Option 11A size range***") can take a longer time — as much as one hour — to bring the house back to a comfortable temperature after the thermostat resets to the high temperature setting. **THIS IS NORMAL.**

If homebuyers find that their new home is too cool when they get out of bed or return home from work, ask them to consider:

- Using a smaller temperature setback, or
- Programming the thermostat to start the high temperature setting earlier so the house is at a comfortable temperature when they get out of bed or return from work.

STEP 13: SPACE AND WATER HEATING EQUIPMENT SELECTION

In order to identify candidate equipment for the housing project, builders and their designers are encouraged to look at both options, those using a separate furnace and water heater, and those using P.9 tested combination systems.

In order to identify candidate systems that satisfy design requirements it is suggested you use the following procedure:

1) **Use NRCan's on-line database listings** of natural gas furnaces, water heaters, and P.9 tested combination systems to identify possible systems (web-links are provide below).
2) **Create a short-list** of candidate furnaces and/or combination systems using the design requirements developed using this decision guide, and other criteria important to the builder.
   - Designers can download the databases, and using a spreadsheet, sort the entire list or only those from manufacturer(s) of interest.
3) **Select a "best fit"** furnace or combination system from the short-listed equipment.
4) **Confirm** that the selected system meets design requirements.

Option 13A: Furnace and Water Heater

Natural Gas Furnaces

NRCan's on-line database of natural gas furnaces is available at:
http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=FURNACES_G

Natural Gas Tankless Water Heaters

ENERGY STAR on-line database of natural gas, tankless water heaters is available at:
https://www.energystar.gov/productfinder/product/certified-water-heaters/results?scrollTo=1199&search_text=&fuel_filter=Natural+Gas&type_filter=&brand_name_isopen=&input_rate_thousand_btu_per_hour_isopen=&markets_filter=Canada&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=energy_factor&sort_direction=desc&page_number=0&lastpage=0

*(SELECT **Type** as "Gas Tankless" and **Markets** as "Canada" from the check boxes on the website)*

Natural Gas Storage Tank Water Heaters

NRCan's on-line database of natural gas, storage tank water heaters is available at:
http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=WATERHEATER_G

Option 13B: Combination Heating System

Natural Gas CSA P.9 Tested Combination Systems

NRCan's on-line database of natural gas CSA P.9 tested combination systems is available at:
http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=P9COMBO

Option 13C: Other Heating Technology

The designer can use this option to specify other types of central, forced-air space heating equipment that satisfies the key design features for the residential application.

Zoned HVAC Equipment:

If a Zoned Installation has been chosen in **STEP 5, Option 5B**:

- The selected HVAC equipment should be equipped with factory-integrated supply zoning from the equipment manufacturer, or
- The designer should specify a suitable zoning package (e.g., zoning dampers, zoning controller, etc.) that is compatible with the selected HVAC equipment, and can be site assembled to provide the zoning functionality.

NOTE TO BUILDERS ON INSTALLATION AND COMMISSIONING:

- All mechanical systems should be installed following all applicable provincial codes and standards.
- For optimum performance to be achieved all mechanical systems should be commissioned by a qualified HVAC technician to verify equipment is setup and operating as designed.

Additional References:

1. **Zoning Decision Guide for Builders**, Natural Resources Canada publication, 2015. PDF available on-line at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/LEEP_Zoning_Guide_for_Builders_e.pdf
2. **Zoning Duct Design Guide**, Natural Resources Canada publication, 2017. PDF available on-line at: http://www.nrcan.gc.ca/energy/efficiency/housing/research/20277
3. **Use of CSA P.9-11 to Specify Combination Space and Water Heating Systems**, Natural Resources Canada publication, 2017. PDF available on-line at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/16-426_Builder-Guide_E_ACC.PDF
4. **ENERGY STAR® for New Home Standard, Version 12.8 and 17.0 Ontario**, Natural Resources Canada publication, 2017. (Use a search engine to find web-link to on-line PDF).

APPENDIX A: Changes to New Homes and Impacts on Space Heating and Cooling Needs

- Mapping Mechanical System Challenges to Possible Solutions

Eight common design situations / industry trends in new housing have been identifies and summarized in Table 13, together with the resulting mechanical system challenges and possible options for improving HVAC System performance and mitigating the impacts of these common design situations.

Following the table, Figure 30 maps these eight design situations to 13 possible options for improving HVAC System performance. This mapping worksheet can help home builders and mechanical designers match their particular design situations / challenges to the most appropriate system changes in order to improve the performance and indoor comfort offered by the new home.

Table 13: Design Changes in New Homes, Mechanical System Challenges and Options for addressing these Challenges

Common Situations / Industry Trends	Resulting Mechanical Challenges	Options for Addressing Challenges
a) **Design heating loads are <u>much lower</u>:** resulting from trends towards more attached housing and multi-unit designs, use of more and continuous insulation, better air sealing and better windows. The revised CSA F280-12 standard for sizing recognizes technology advances over the last 25 years, resulting in large reductions in design loads. Singles and towns that traditionally would have used a gas furnace with an input of 80,000 Btu/h, now often only need one with 30,000 Btu/h input. Stacked back-to-back towns can require well under half this amount. For most of the heating season, the needed output is less than half the design heating load.	• Oversizing of furnaces can result in short heating cycles, • Oversizing of furnaces results in larger ductwork with the associated increases in boxing and bulkheads.	• **Close sizing:** Sizing heating equipment so that it more closely matches design loads. • **Staging or modulation:** Select heating equipment with two or more output stages.
b) **Mismatch of house heating and cooling loads:** With reduced heating loads and large windows driving up air conditioning requirements, duct sizing and design airflows are often determined by cooling requirements, which can be substantially higher than heating requirements.	• High cooling loads require larger A/C units, higher design airflows and larger ducts with the associated increases in boxing and bulkheads. • With higher airflows, heating systems will often be oversized compared to design heat loss values and can result in short heating cycles.	• **Coordinate HVAC Design and Window Selection:** Choose windows with a lower Solar Heat Gain Coefficients (SHGC) to balance heating and cooling airflow requirements. • **Staging or modulation:** Select heating equipment with two or more output stages to better match the lower heating requirements.
c) **Increasing window to wall ratio** with one or two rooms with a lot of glass. Great rooms with large glazing areas and windows no longer evenly spread around the house. Townhouses and back-to-backs with glazing on only one or two sides. Challenging to achieve uniform comfort conditions, especially when the glazing faces west.	• Large glazing areas, facing south and west can increase cooling loads significantly; concentration of glazing in one area can lead to local hot spots which may not be representative of indoor conditions throughout the home leading to comfort complaints.	• **Coordinate HVAC design and window selection:** Choose windows with a lower Solar Heat Gain Coefficient • **Zoning Supply Ducts**

Common Situations / Industry Trends	Resulting Mechanical Challenges	Options for Addressing Challenges
d) Taller, narrower homes that have finished basements: Density requirements and land values are driving a trend towards tall, narrow homes where even the basements are finished.	• Greater stratification -- more hot air pooling at the top of the house and cool air at the bottom. • Homeowners' demand of *"above-grade comfort conditions"* in finished basements is very difficult to achieve due to large variations in heating and cooling loads and airflow requirements with the changing seasons.	• **Coordinate** duct design and framing layout • **Zoning Supply Ducts** • **Duct sealing** • **High wall supplies** on top floor • **Upgraded return** to pull air from top and bottom of home • **Closet-sized mechanicals** • **Low returns in basement** (with continuous air circulation)
e) Mismatch of basement heating and cooling airflow requirements: Basements typically require similar levels of heating as above grade floors but less than a quarter of the cooling.	• The HVAC system is typically balanced for the heating mode. This will overcool the basement in summer as homeowners typically do not adjust ductwork balancing between seasons. • High duct leakage can exist and is concentrated in the basement, which will tend to produce overcooling even with rebalancing of supply ducts.	• **Zoning Supply Ducts** • **Duct Sealing** • **Continuous air circulation**
f) Open concept designs that maximize finished space: Smaller footprint homes need to maximize usable space.	• Little space for vertical ductwork to reach upper floors and need to minimize bulkheads.	• **Coordinate** duct design and framing layout • **Zoning Supply Ducts** • **Smaller ducts:** use mid or high static pressure / velocity supply ducts • **Closet-sized mechanicals and/or multiple air-handlers**
g) Uncomfortable upper floor sleeping conditions during heat waves: Homeowners have greater comfort expectations in all areas of the home.	• Central A/C units shut down overnight once the thermostat on the main floor is satisfied, with hot air still pooled on the upper level(s) of a multi-level home.	• **Zoning Supply Ducts** • **Duct sealing** • **High wall supplies** on top floor • **Thermostat location** (move to uppermost floor) • **Return to top of home** (with continuous air circulation)
h) Cold clammy summer A/C conditions: Air conditioning system cools without removing enough moisture from the air so the house gets cold and clammy, moisture may condense in colder basements, and stored items may mold.	• Oversizing of A/C units and setting cooling airflow too high can result in short cooling cycles and poor dehumidification of indoor air.	• **Close sizing** of **A/C capacity** to design cooling load • **Optimizing airflow in cooling** (e.g., dehumidification control cycle; leaving air temperature control, etc.) • **Staging or modulation of cooling** • **Continuous air circulation**

Forum presentation slides for some of the common situations / industry trends, as well as some options for addressing challenges are provided at the end of this appendix.

Other illustrations are available in the main body of the **Master Planning and Decision Guide for Natural Gas Mechanical Systems**.

Figure 30 maps the eight design situations described in Table 13 to thirteen possible options for improving HVAC System performance.

- Builders and designers can use this **mapping worksheet** to match their particular design situations / challenges with the most beneficial system changes in order to improve the performance and indoor comfort offered by the new home.

Example: Identifying options for enhancing mechanical system performance

For example, if a particular house design is best described as:

- tall and narrow, with finished basement" (i.e., situation "d"), and

Previous experience with similar designs have shown homeowner issues related to:

- cold basements in summer (i.e., situation "e"), and
- uncomfortable sleeping conditions on upper floors (i.e., situation "g"),

These three situations are highlighted in Table 26 by yellow bars.

OPTIONS FOR ADDRESSING MECHANICAL CHALLENGES >>>> / Common Situations or Industry Trends	Close Sizing of equipment	Staged / Modulating equipment	Window Sel'n part of HVAC design (SHGC)	Framing Layout part of HVAC design	Zoning of supply ducts	Duct Sealing	Supply outlet placement	Air return placement & design	Med. or high static pressure systems	Closet-sized mechanicals	Continuous air circulation	Cooling airflow optimization/control	T-stat placement / remote temp. sensor
a) Design Heating Load are much lower	✓	✓											
b) Mismatch of house heating & cooling loads		✓	✓										
c) Increases in window to wall ratios			✓		✓								
d) Taller, narrow homes with finished basements				✓	✓	✓	✓	✓		✓	✓		
e) Mismatch of basement heating & cooling CFM					✓	✓					✓		
f) Open-concept design challenges				✓	✓				✓	✓			
g) Uncomfortable sleeping conditions on upper floors					✓	✓	✓	✓			✓		✓
h) Cold and clammy conditions when air conditioning	✓	✓									✓	✓	

Figure 30: Mapping of 8 Common new-home design situations to various design options for addressing mechanical challenges

Identifying Priority Options

Builders and their designers may want to consider the following options, each with checkmarks on all three situations (i.e., d, e and g), as shown by the red circles:

- Zoning of supply ducts;
- Duct sealing; and,
- Use of continuous air circulation.

Other options to consider, each with checkmarks on two of the three situations (i.e., d and g) are:

- Supply outlet placement; and,
- Air return placement and design.

A copy of the **mapping worksheet** is provided on the next page for your use.

Mapping of Mechanical Challenges and Possible Solutions Worksheet

- **Copy and use this worksheet to identify priority options for enhancing mechanical system performance**

Builder Name: ____

Designer Name: ____

House Identifier: ____

The results are to be applied to:
( ) this specific home only, or
( ) subdivision of similar homes (mechanical designers to use their experience to modify to others homes as needed).

Instructions for use:

1) In the left-hand column, identify one or more COMMON SITUATIONS / MECHANICAL CHALLENGES that you face in your housing projects and HIGHLIGHT those rows.
2) The CHECKMARKS in each of the HIGHLIGHTED ROWS will identify VARIOUS OPTIONS you may want to consider for addressing your mechanical challenges.
3) List the TOP THREE OPTIONS you would like to consider on your next housing project in the spaces provided below.

OPTIONS FOR ADDRESSING MECHANICAL CHALLENGES >>>> Common Situations or Industry Trends	Close Sizing of equipment	Staged / Modulating equipment	Window Sel'n part of HVAC design (SHGC)	Framing Layout part of HVAC design	Zoning of supply ducts	Duct Sealing	Supply outlet placement	Air return placement & design	Med. or high static pressure systems	Closet-sized mechanicals	Continuous air circulation	Cooling airflow optimization/control	T-stat placement / remote temp. sensor
a) Design Heating Load are much lower	✓	✓											
b) Mismatch of house heating & cooling loads		✓	✓										
c) Increases in window to wall ratios			✓		✓								
d) Taller, narrow homes with finished basements				✓	✓	✓	✓	✓		✓	✓		
e) Mismatch of basement heating & cooling CFM					✓	✓					✓		
f) Open-concept design challenges				✓	✓				✓	✓			
g) Uncomfortable sleeping conditions on upper floors					✓	✓	✓	✓			✓		✓
h) Cold and clammy conditions when air conditioning	✓	✓									✓	✓	

LIST YOUR PRIORITY OPTIONS HERE:

OPTION #1: ____

OPTION #2: ____

OPTION #3: ____

Other Notes: ____

The following Graphics illustrate:

- Some common situations / industry trends in today's housing
- 5 effective ways to improve mechanical system performance in today's housing

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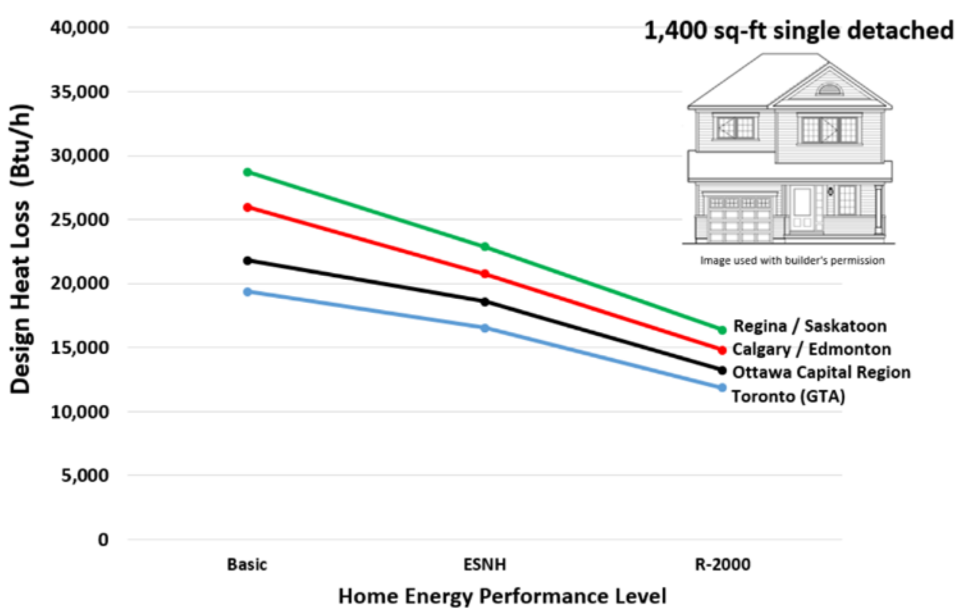
a) Design heating loads are <u>much lower</u>



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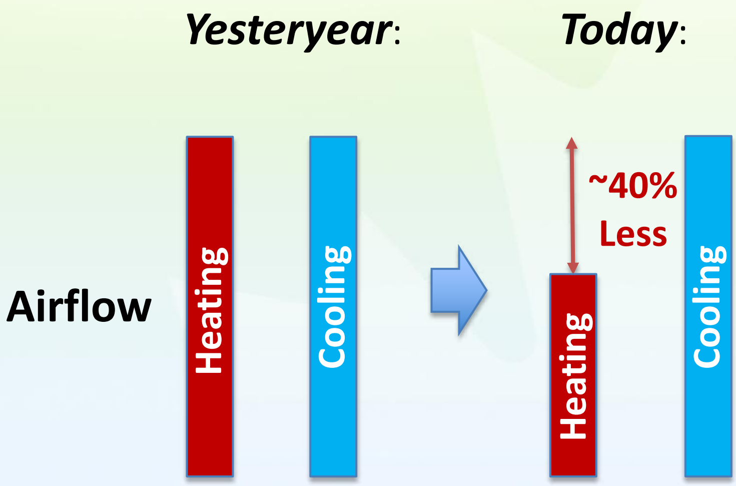
b) Mismatch of home heating & cooling loads



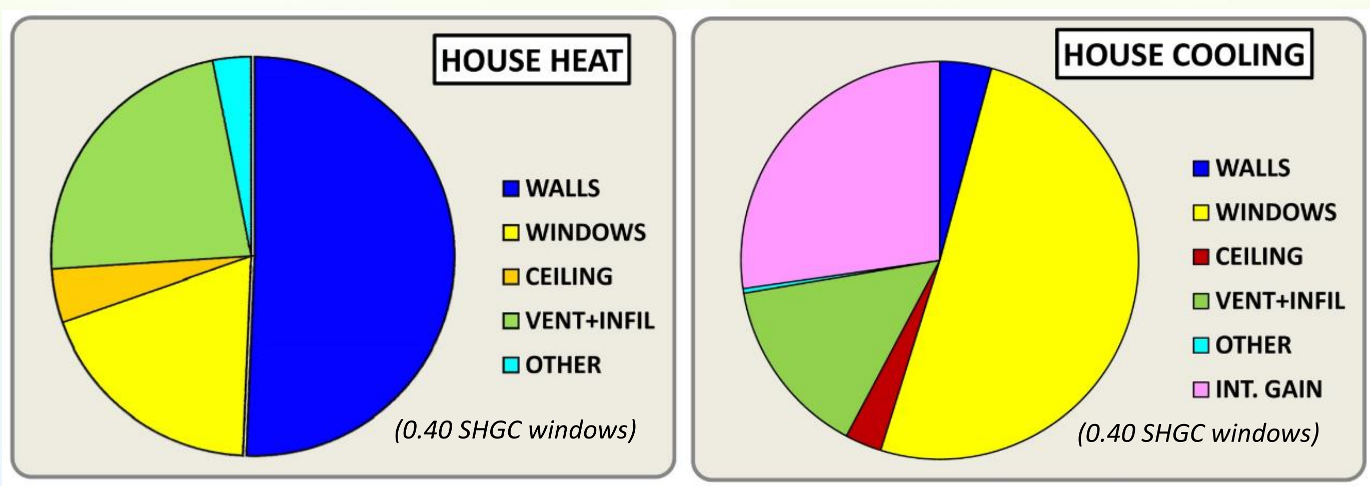
Design Cooling Loads

- No change in window Solar Heat Gain Coefficient (SHGC)
- Sometimes more glazing and more concentrated glazing

Duct Sizing

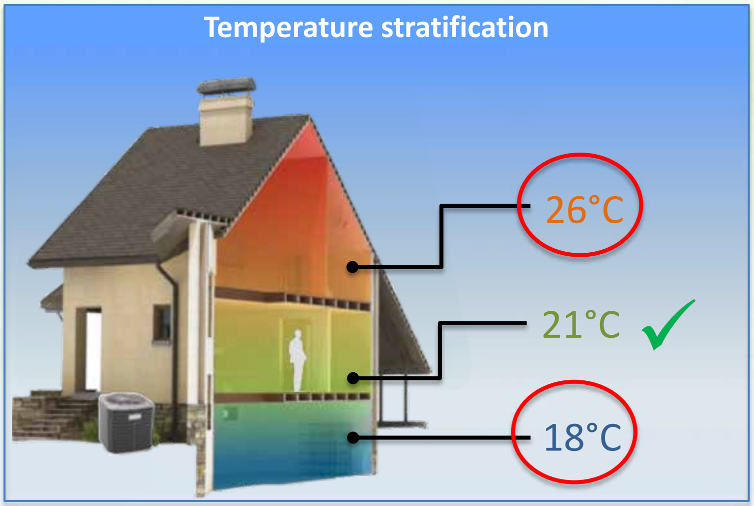
- often based on cooling airflow requirements – even where cooling is not installed.

c) Increase in window to wall ratios



d) Taller, narrower homes with finished basements

- Temperature stratification between floors



- *Upstairs is too hot*
- *Main floor is comfortable*
- *Basement is too cool*

5 effective ways to improve mechanical performance in today's housing

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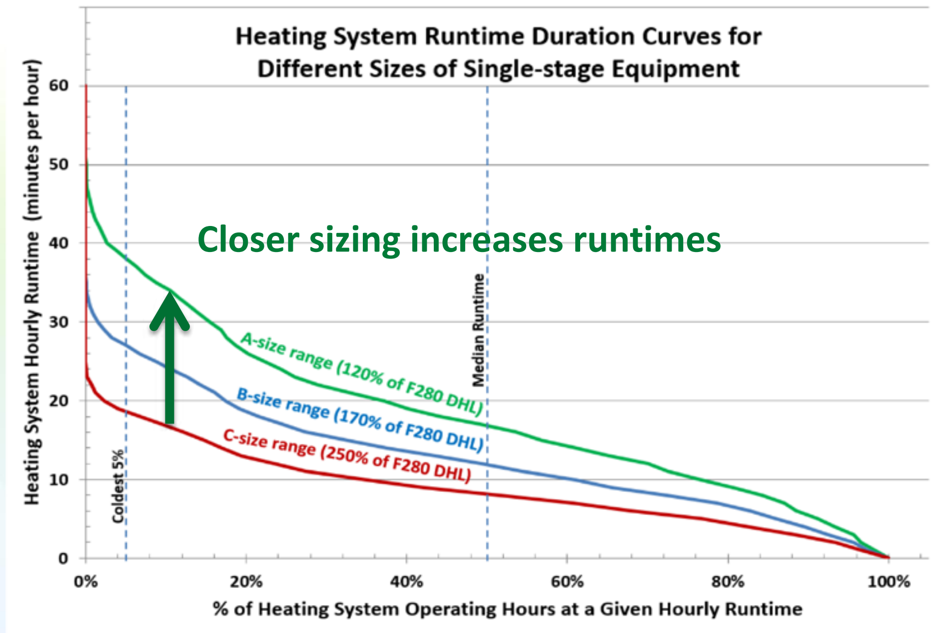
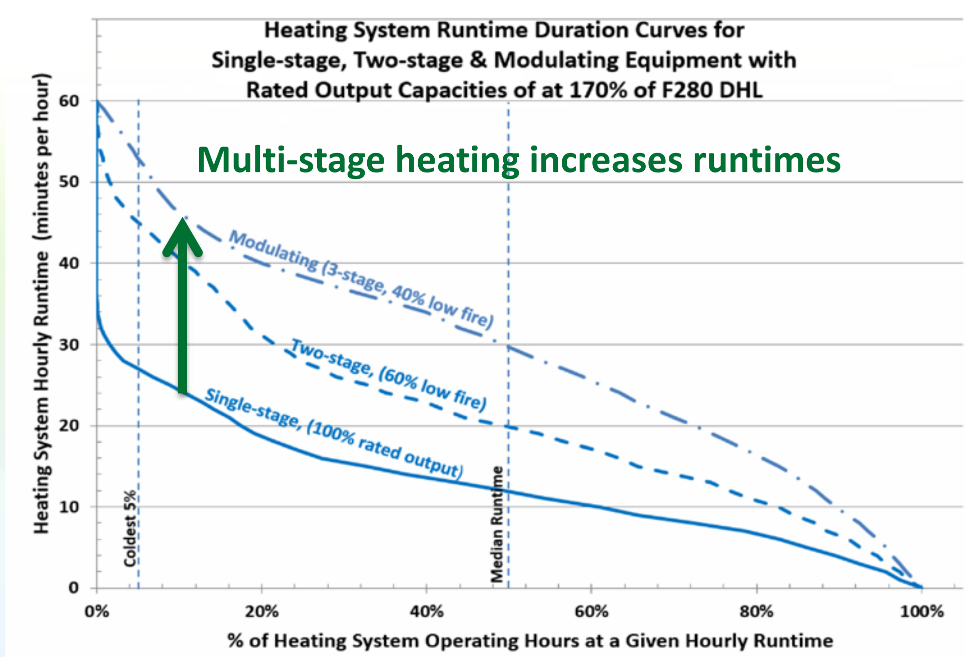
1. Close-sizing of Heating Capacity to Design Heat Loss



2. Staging or Modulating Heating Capacity



Window ratings

Usi (.. or Rsi, R, U)

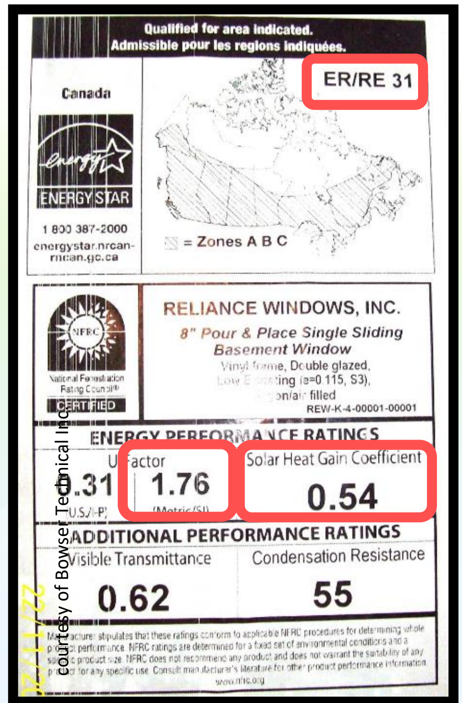
– Heat loss and gain through glass and frame

SHGC – Solar Heat Gain Coefficient

– Percentage of sunlight transmitted as heat

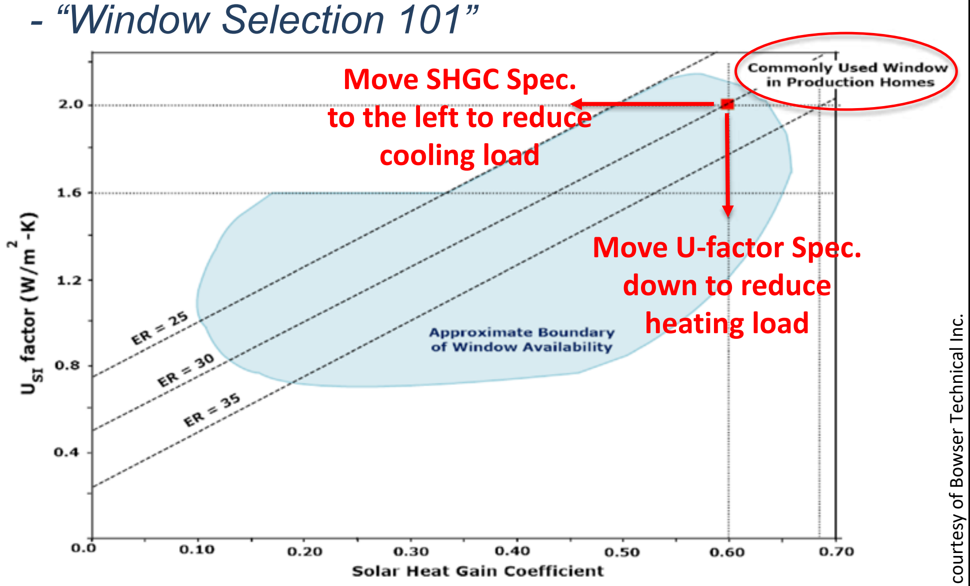
ER – Energy Rating

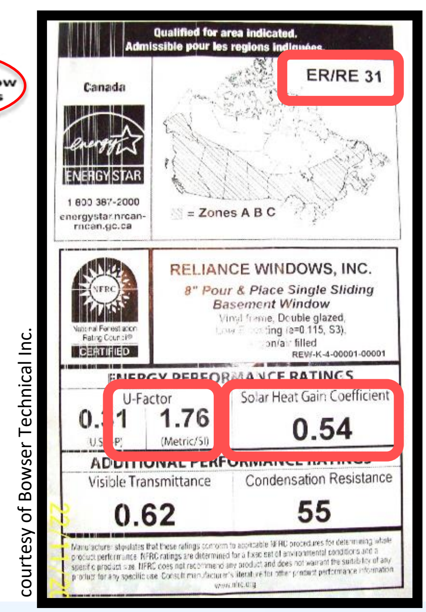
– A standardized rating of performance during the space heating season only.
– Combines: U-value, air infiltration and SHGC



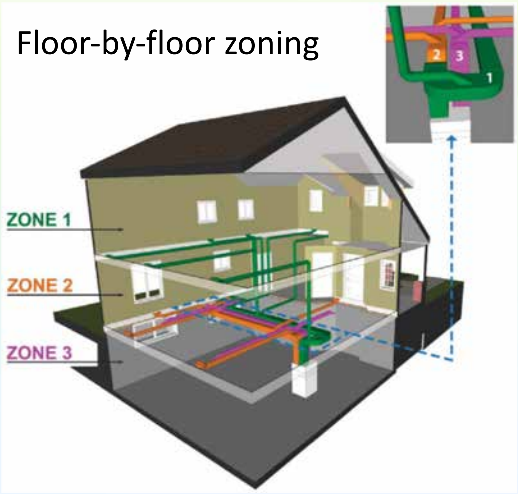
3. Coordinating Window Selection with HVAC Design

- "Window Selection 101"





4. Forced Air Zoning
to minimize vertical temperature stratification



5. Duct Sealing
to move air where it is designed to go

Without sealing:
duct leakage is typically 30-40% or more in production housing

Leakage* Rates after sealing:
5 to 15% with Paint-on Mastic / Tape
1 to 5% with *'sticky dust'* duct sealing

* Leakage data and images courtesy of Bowser Technical Inc.

APPENDIX B: Demonstration of Using the Master Planning & Decision Guide for Natural Gas Mechanical Systems

- Showing how builders can collaborate with their HVAC designers to enhance comfort and save cost

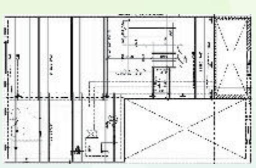
The following slides have been taken from a LEEP Forum Presentation made by a builder and their HVAC Designer that demonstrates how using the **Master Planning and Decision Guide for Natural Gas Mechanical Systems** may result in HVAC system designs that:

- Enhance home-buyer comfort, and
- Reduce builder costs.

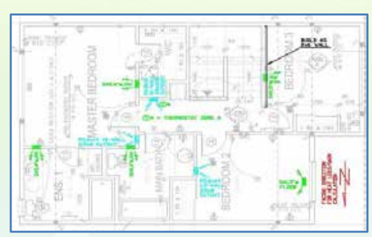
Starting point: Builder’s Heating and Cooling Goals
Improve comfort
Increase efficiency
Reduce bulkheads and box outs
Reduce mechanicals footprint
Add saleable benefits
Reduce call back risks in a market with heightening customer expectations
… all while addressing costs, timelines, and keeping consumer education feasible

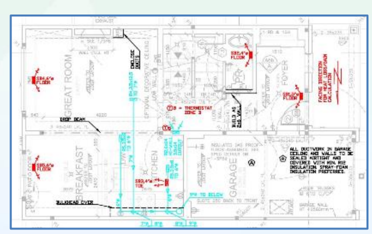
Using the Guide

Builder & Designer Preparation → **Builder & Designer Meeting** → **Design**

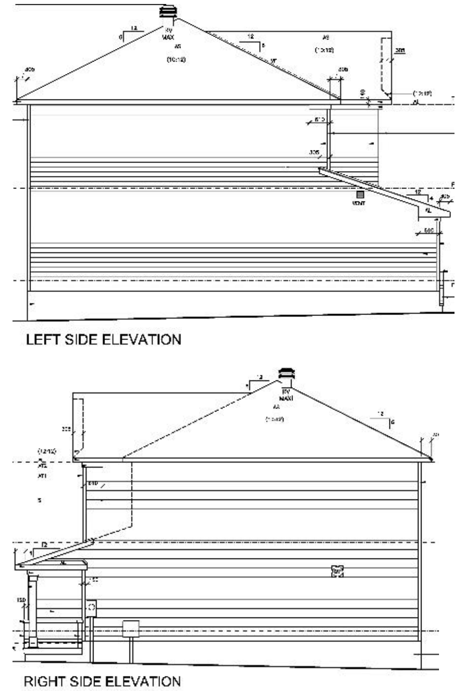


Load Calculations				
Component	Heating Btuh	%	Cooling Btuh	%
Walls	3156	15.6	355	1.7
Glazing	6268	31.0	11131	53.5
Door	169	0.8	6	0.0
Ceiling	1502	7.4	550	2.6
Floors	3023	15.0	54	0.3
Infiltration	4566	22.6	101	0.5
Ventilation	1523	7.5	120	0.6
Internal Gains			3686	17.7
Latent			4801	23.1





Want to get an HVAC design for this 1400ft^2 '<u>Case Study</u>' house



Impact of Windows on Design Loads

- Builder provided ER <u>Only</u>
- Want to avoid liability for undersizing A/C:
- Assume high Solar Heat Gain Coefficient (SHGC) of 0.60 to 0.65.

Let's see what happens as a result.

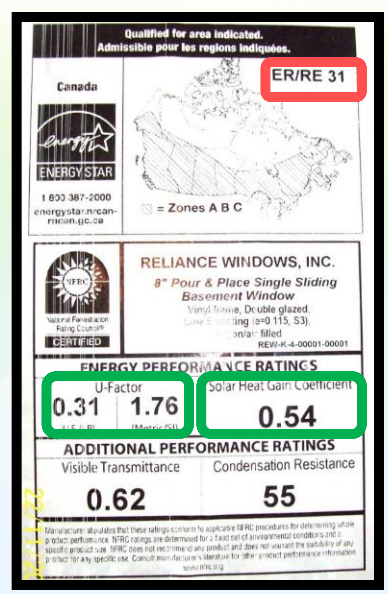
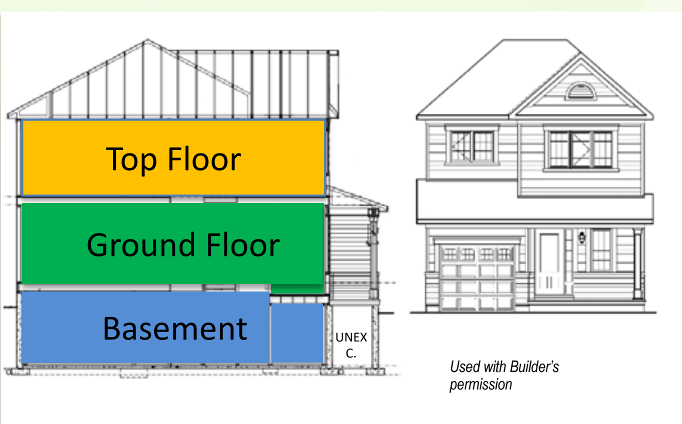


Image courtesy of Bowser Technical Inc.

CASES	SHGC not provided	SHGC specified and provided
SHGC	**0.60** ('Typical' assumption)	**0.40**
U-value	0.25	0.25
F280-12 Design Heating Load	23,301 Btu/h	23,301 Btu/h
F280-12 Design Cooling Load	20,200 Btu/h (1.68 tons)	16,643 Btu/h (1.39 tons)
Furnace Selected	40,000 Btu/h	40,000 Btu/h
Heating Airflow	600 cfm (59°F rise)	600 cfm (59°F rise)
A/C Selected	2 ton	1.5 ton
Cooling airflow	**800 cfm**	**600 cfm**

Even when no cooling is installed, an assumed SHGC will result in larger ductwork, with more bulkheads and more box outs.

STEP 8: Prerequisite Load Calcs



Space Heating and Cooling Loads

Component of Space Conditioning Design Load	Space Heating Design Heat Loss (using F280-12) (Btu/h)	Space Cooling Design Heat Gain (using F280-12) (Btu/h)
Top Floor	7,447	6,939
Ground Floor	7,687	6,756
Basement	8,167	2,948
Total Design Load	**23,301**	**16,643**

Ventilation

Principal Ventilation Requirement
60 cfm

Domestic Hot Water Heating Load

Required minimum DHW flowrate at 49°C (120°F)	Minimum wintertime cold water supply temperature.
15 L/min (4 US GPM)	10°C (50°F)

Completed Checklist of Key Design Features

Step	Builder to Complete in Consultation with Designer	Option A	Option B	Option C	Additional Information / Notes
1	House Type	Multi-unit Town	Multi-level Single	Bungalow	Number of levels with basement: 3
2	Supply Outlet placement	Perimeter Supply	Central Supply	Hybrid Supply	High-wall on 2nd Floor
3	Supply Duct Velocity /Static Pressure	Low-velocity	Medium-velocity	High-velocity	
4	Supply Duct Zoning	Single-Zone supply ducting	Floor-by-Floor zoning	Other zoning approach	If C chosen, describe approach:
5	Equipment Zoning	Non-Zone *Non-zoned equipment / single-zone ducting*	Fully Zoned* *Multi-zoned equipment / zoned supply ducting*	Zone-Ready* *Non-zoned equipment / zoned supply ducting*	* Requires either Option B or C in Step 4
6	Return Inlet placement	Traditional return	Simplified return	[not applicable]	
7	Duct Sealing	Base-level sealing	ESNH sealing	ESNH sealing with leakage testing	
Step	**Designer Led Load Calculations**	**Space Heating Load**	**Space Cooling Load**	**Domestic Hot Water (DHW) Load**	**Additional Information / Notes**
8	Prerequisite Design Load Calculations	Design Heat Loss (DHL): 23,301 Btu/h	Design Heat Gain (DHG): 16,643 Btu/h	DHW flowrate: 15.0 L/m at inlet T of: 10°C	
Step	**Designer Led Steps**	**Option A**	**Option B**	**Option C**	**Additional Information / Notes**
9	Cooling Capacity	1 ton	1-1/2 tons	Other: ____ tons	
10	Cooling Staging / Dehumidification (DH) strategy	Single-stage cooling with no DH strategy	Single-stage cooling with DH controls	Staged or modulating cooling with DH controls	
11	Space Heating Capacity	100% to 125% of DHL	126% to 175% of DHL	Greater than 175% of DHL	*Note: DHL is the CSA F280 design heat loss*
12	Heating Equipment Staging / Modulation	Single-stage output	Two-stage output	Modulating output *(3 or more stages)*	
13	Space and Water Heating Equipment Selection	Furnace and Water Heater	Combination Heating System	Other Heating Technology: ____ *(describe)*	Rated space heating output: 38,400 Btu/h Supply zoning: Yes / No Rated DHW heating capacity: 18.3 L/min

Summary of design differences for this design

With designer given permission using checklist

Traditional Design Approach	Collaborative Design Approach
Ducting sized for 800 cfm	Ducting sized for 600 cfm
No zoning	Zoning by floor
No Staging	2-Stage furnace; 1-stage AC (where AC requested)
Low-velocity, large rectangular trunks	Mid-velocity, round trunks & fittings, smaller overall
Perimeter supply outlets on all floors	Hybrid supply: high-wall supply outlets on upper floor
Returns in all rooms	Simplified returns: 1 High, 1 Low + others as required

Builder's goals	How are we doing?
Improve comfort	More even comfort on all levels (zoning, right sizing, two staged heating, round ducts easier to seal, duct sealing)
Increase efficiency	Reduced overheating and overcooling. Potential to set back or set forward unused zones.
Reduce bulkheads and box outs	Eliminated basement bulkheads and most box outs on other floors. Fits more easily with open concept design.
Reduce mechanicals footprint	Moved registers off floor in bedrooms
Add saleable benefits	Zoning - for those that have lived in a multi-storey home
Reduce call back risk in a market with heightening customer expectations	All comfort improvements above
... all while addressing costs	Simplified returns, downsized ductwork, eliminated box outs

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Photo courtesy Bowser Technical

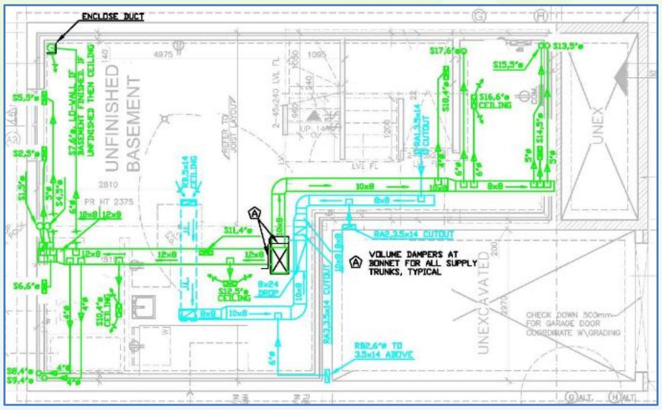
MID-VELOCITY DUCTWORK

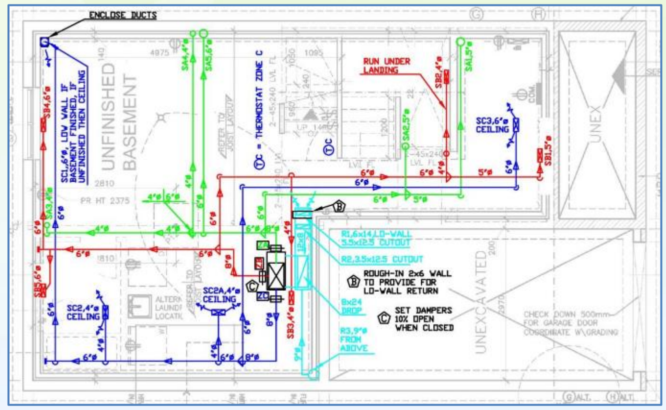
- **Trunk Ducts Can be round (up to 10")**
- **Custom Fittings not required.**
- **Similar to HRV ductwork**
- **Easier to seal for reduced air leakage**

Smaller Ducts - More Head-room in Basement

Main supply and return plenums – 12”x8” and 10”x 8”

ALL Zones -- Max 6”ø ducts outside mechanical room





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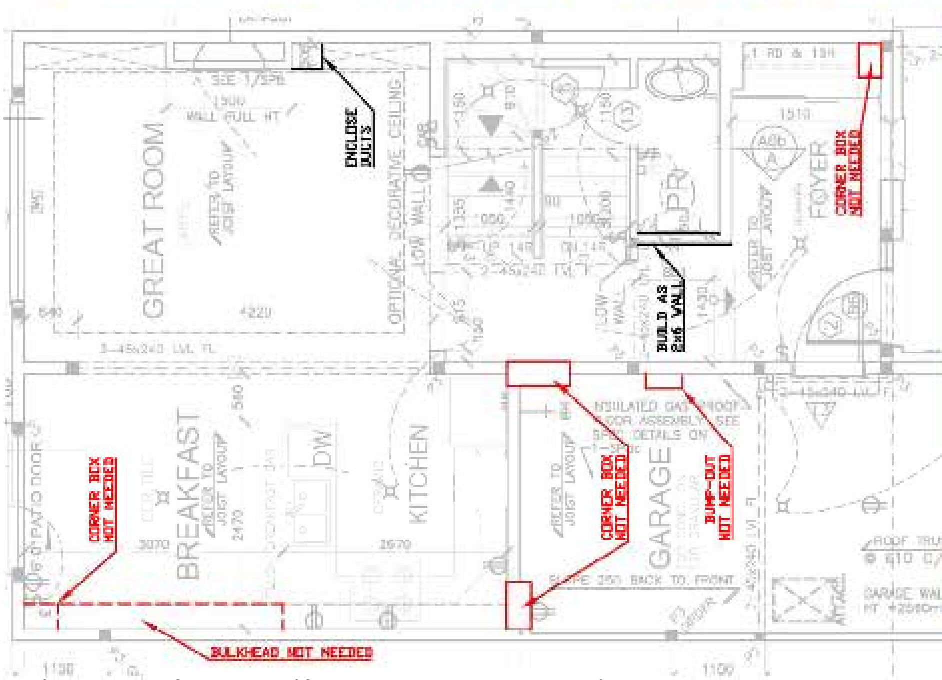
Fewer bulkheads, corner boxes



FRAMING CHANGES MAIN FLOOR

Black shows added boxes and bumpouts

Red boxes and bulkheads are <u>not needed</u> with new design

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APPENDIX C: Key Design Features Checklist for Natural Gas Mechanical Systems

Builder Name:

Designer Name:

House Identifier:

The results are to be applied to:

( ) this specific home only, or

( ) subdivision of similar homes (mechanical designers to use their experience to modify to others homes as needed).

COMPLETION INSTRUCTIONS: Circle one option per step; Provide additional information in shaded boxes.

Step	Builder to Complete in Consultation with Designer	Option A	Option B	Option C	Additional Information / Notes
1	**House Type**	Multi-unit Town	Multi-level Single	Bungalow	**Number of levels** with basement: ____
2	**Supply Outlet placement**	Perimeter Supply	Central Supply	Hybrid Supply	
3	**Supply Duct Velocity /Static Pressure**	Low-velocity	Medium-velocity	High-velocity	
4	**Supply Duct Zoning**	Single-Zone supply ducting	Floor-by-Floor zoning	Other zoning approach	If C chosen, describe approach: ____
5	**Equipment Zoning**	Non-Zone *Non-zoned equipment / single-zone ducting*	Fully Zoned* *Multi-zoned equipment / zoned supply ducting*	Zone-Ready* *Non-zoned equipment / zoned supply ducting*	* Requires either Option B or C in Step 4
6	**Return Inlet placement**	Traditional return	Simplified return	[not applicable]	
7	**Duct Sealing**	Base-level sealing	ESNH sealing	ESNH sealing with leakage testing	
Step	**Designer Led Load Calculations**	**Space Heating Load**	**Space Cooling Load**	**Domestic Hot Water (DHW) Load**	**Additional Information / Notes**
8	**Prerequisite Design Load Calculations**	Design Heat Loss (DHL): ____	Design Heat Gain (DHG): ____	DHW flow rate: ____ at inlet T of: ____	
Step	**Designer Led Steps**	**Option A**	**Option B**	**Option C**	**Additional Information / Notes**
9	**Cooling Capacity**	1 ton	1-1/2 tons	Other: ____ tons	
10	**Cooling Staging / Dehumidification (DH) strategy**	Single-stage cooling with no DH strategy	Single-stage cooling with DH controls	Staged or modulating cooling with DH controls	
11	**Space Heating Capacity**	100% to 125% of DHL	126% to 175% of DHL	Greater than 175% of DHL	***Note:*** *DHL is the CSA F280 design heat loss*
12	**Heating Equipment Staging / Modulation**	Single-stage output	Two-stage output	Modulating output *(3 or more stages)*	
13	**Space and Water Heating Equipment Selection**	Furnace and Water Heater	Combination Heating System	Other Heating Technology: ____ *(describe)*	Rated space heating output: ____ Supply zoning: Yes / No Rated DHW heating capacity: ____