HVAC Team Research Review

By

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1. INTRODUCTION

There are various important aspects to be taken into consideration when designing and building a house for Team Montreal. An important consideration in the design of a home is HVAC system, or Heating, Ventilation and Air Conditioning. The HVAC system's purpose is threefold. It will regulate air quality, air movement, and comfort inside the house. To achieve these objectives, the HVAC system will have control over air contaminants and fresh air intake, air distribution, and air temperature and humidity respectively. Moreover, as Team Montreal, we have set ourselves goals in addition to the objectives above. Firstly, the householders will have to do as little maintenance as possible on the HVAC system. Secondly, we want to design a silent system so that the householders can go about without any noise discomforts. Finally, we will strive to design the best cost-efficient, low-powered HVAC system.

Active energy systems

Active energy systems will be our main temperature regulating systems in our house. Base board heaters and lower heating technologies will be rejected because of their low efficiencies. All heating and cooling will be done by technologies having coefficient of performance greater than 1, i.e. technologies resembling thermal heat pumps with electric heaters along with the distribution of forced air and the use of solar water heating systems (indirect circulation systems). That being said, since this is a net-zero house, we want to reduce our dependence on active energy systems as much as we can. Maximizing passive energies combined with heat recovery technologies, as discussed below, are key to reduce the house's energy consumption as well as its energy cost.

Passive energy systems

Even though passive energy systems are not our main temperature regulation systems, they are our most complex in our house and can be addressed by many different angles. One of these angles is cleverly designing the architecture of the house. Another one is the combination of fenestration and thermal heat mass. We will design the fenestration of the house as well as adjusting the widow glaze so that the Sun’s rays heat up the thermal heat mass during the winter days. During the winter nights the thermal heat mass will release the heat accumulated during the day, hence reducing the energy consumption of the house during the winter nights. A third angle are phase changing materials (PCMs). Research has been done on PCMs under the title “Research”. Finally, the fourth angle is the heat recovery systems. To minimize heat loses, heat wastes from heating systems, human presence, appliances, etc. will be recycled through air-to-air heat exchangers before being exhausted outdoors. Moreover, water-to-water heat exchangers will also be used to extract the heat form the outgoing gray water to the ingoing tap water.

Ventilation

Since our home will have a high air tight value, good ventilation is a must. The ventilation system has the burden of delivering a fresh and steady flow of air to each room in the house. Furthermore, for the householder’s comfort and safety, the ventilation system will also control the humidity and contaminant levels in the house. An enthalpy wheel and air purifiers will be used to this effect. The wheel is coated with desiccant material that will transfer heat and humidity to or from the house while the air purifiers will filter out the contaminants. Through careful design of the air ducts and the fan blades, the ventilation system will be quiet enough to go unnoticed by the householders.

2. RESEARCH

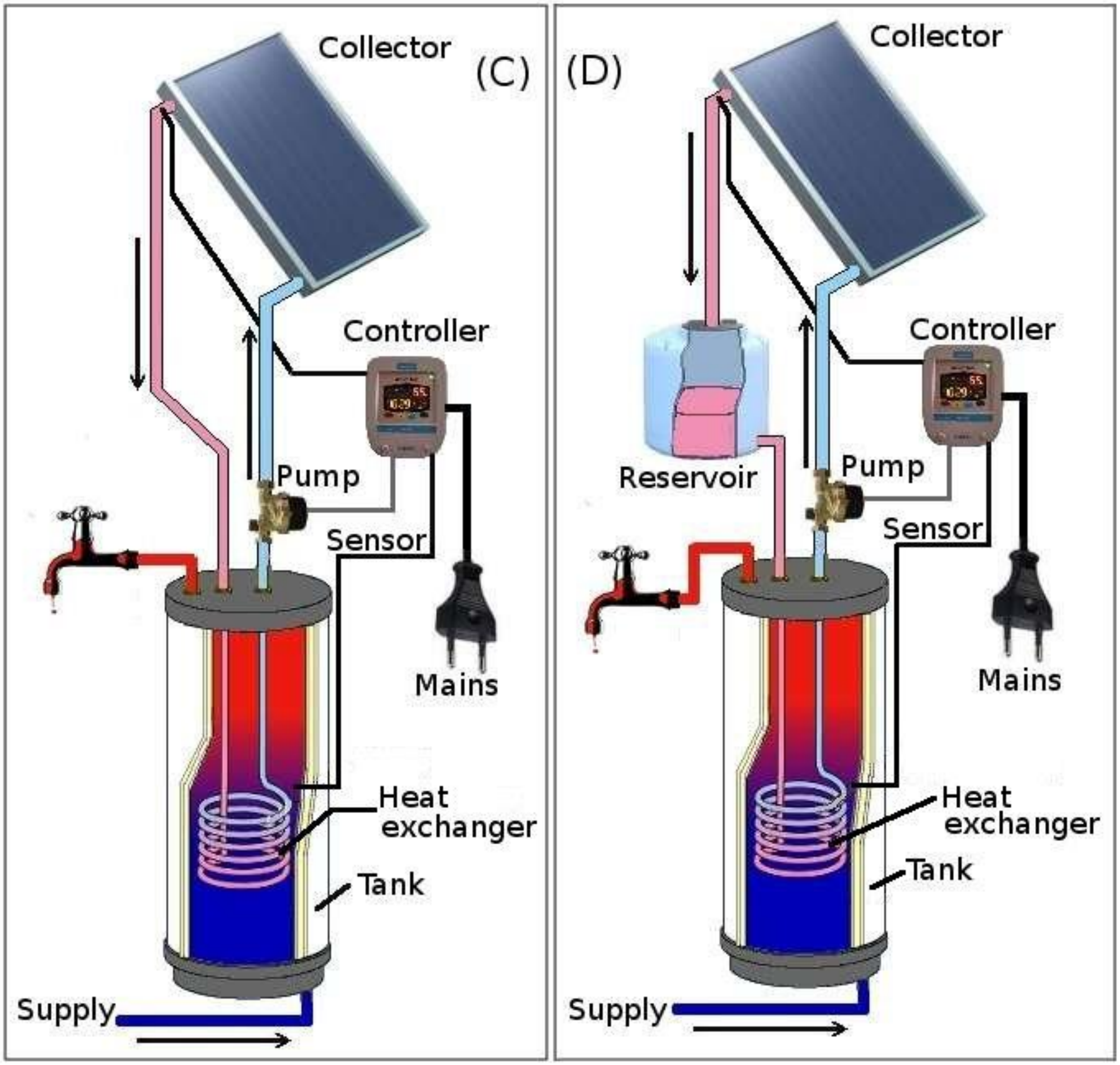
2.1 ACTIVE SOLAR WATER HEATING SYSTEMS

Solar Water Heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

We will be using Indirect Circulation systems: Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates **prone to freezing temperatures.**

Indirect or **closed loop** systems use a heat exchanger that separates the potable water from the fluid, known as the "heat-transfer fluid" (HTF),that circulates through the collector. The two most common HTFs are water and an antifreeze/water mix that typically uses non-toxic propylene glycol. After being heated in the panels, the HTF travels to the heat exchanger, where its heat is transferred to the potable water. Though slightly more expensive, indirect systems offer freeze protection and typically offer overheat protection as well.

(http://energy.gov/energysaver/articles/solar-water-heaters)



Indirect active systems: (C) Indirect system with heat exchanger in tank; (D) Drainback system with drainback reservoir. In these schematics the controller and pump are driven by mains electricity

Active systems use one or more pumps to circulate water and/or heating fluid in the system.

Though slightly more expensive, active systems offer several advantages:

- The storage tank can be situated lower than the collectors, allowing increased freedom in system design and allowing pre-existing storage tanks to be used.
- The storage tank can always be hidden from view.
- The storage tank can be placed in conditioned or semi-conditioned space, reducing heat loss.
- Drainback tanks can be used.
- Superior efficiency.
- Increased control over the system

The normal lifespan of a solar domestic hot water system is 25 years. A well-maintained system can certainly over last that. A proper installation of your solar hot water system will certainly help prolong the lifespan of your system and it's associated components.

There are many different types of thermal solar systems which cater to different results. A start-up kit will generally start around $6,000

There is very little maintenance: a check-up of the glycol every other year should be performed to check for it's freezing point and PH.

Solar storage tank:

We will calculate approximately 15-20 gallons of solar storage for each of the occupants of the house.

Collectors:

For an area like Québec, we calculate approximately 0.75 to 1 square foot of collector surface for one gallon of solar water storage. For example, a family of 4 adults will use about 80 gallons of hot water per day, we will recommend a storage tank of 80 gallons with a collector surface averaging 60 square feet or the equivalent of 2 collectors.

2.2 Thermal Heating Mass

Thermal heating mass will be used in the proposed HVAC design to contribute to the energy regulation within the house. This element is meant to absorb and distribute heat from sunlight, and cool down in its absence. The thermal behavior of the chosen material should contribute to an efficient heating regulation parallel to the HVAC system (pumps, heat exchangers, compressors, etc.).

An efficient thermal mass agent should have a high specific heat capacity and high density. Notice how water has the highest heat capacity when compared to other common thermal mass materials such as concrete, wood, and soil. Water usage as a thermal mass agent is mostly in **water walls**, which are part of the walls. Due to modularity and the fact that water walls would include a rather challenging system to implement in the already complex proposed design, <u>we would not recommend water as a thermal mass agent.</u>

An ever efficient thermal mass agent should be functional only on **passive solar design (PSD)**; that is, it should work based on the orientation of the house, the layout of windows and ventilation ducts, insulation, airtightness, and the efficient shadowing, amongst others (Thompson).

Different from water, **masonry materials** are good thermal heating mass agents. The common materials of masonry construction are brick, stone, marble, granite, travertine, limestone, cast stone, concrete block, glass block, stucco, tile, and cob. Amongst these materials, **concrete** (heat capacity of 0.88J/(g*K)) is the most practical and efficient material to be used as thermal mass (Thompson, Ghoreishi, Hacker). Because the (preliminary) design of the house imposes modularity on all components, in-situ concrete is not a valid option because it violates this task. We would like to use either precast concrete blocks or panels. In addition, we would like the concrete to be properly curated so that its thermal properties are improved. These panels can be used in the exterior envelope, interior walls, frame, and floor and roof slabs.

There is also the possibility to use active thermal mass in precast structures. We would let air to circulate in the voids of hollow core floor and roof slabs, which would reduce the size of the required mechanical system, and thus create energy savings in replacing some unnecessary HVAC system devices (e.g. extra piping).

<u>Benefits of sustainable precast concrete as thermal mass</u>

- Relatively high heat capacity and thermal conductivity
- High density

- Panels may in general be removed from the wall individually without affecting the stability of other units or the structure itself
- Waterproof, if given a low water-cement ratio

Material: concrete

Desired composition & process: thermally curated, added R-value, low water-cement ratio

Type/form: modular removable panels

Average strength: up to 5000psi, stronger than regular casted blocks and walls

Layout on house

- Exterior: walls
- Interior: walls and floors

Cost variables: Grade, volume, type of reinforcement

(the following values are for reference only)

For walls: 55$ -$65 per linear foot of wall (source: (http://www.toolbase.org/Technology-Inventory/Foundations/precast-concrete-panels); There is not much information about cost of curated concrete panels for housing purposes so this value is yet to be confirmed. In the meantime

Manufacturers & suppliers in the QC area

- Synstone Concrete Cladding Panels http://www.synstone.com/
- Armtec Infrastructure products www.armtec.com
- Precast concrete suppliers guide http://www.frasers.com/search/concrete-pre-cast?cid=10647382607

Notes on References:

1. **Thermal mass for housing**

Guy Thompson

The Concrete Centre

> Thermal mass can be achieved using a variety of different methods and materials. However, in practice,concrete - either blocks or panels, precast or in-situ - has been found to offer the best levels of thermal mass. Taking full advantage of thermal mass requires an integrated construction approach that includes a balance between orientation, glazing, ventilation and shading, as well as the provision of a high standard of insulation and airtightness.

Design of the house must account for the orientation of the house, the windows, effective shading, and collaboration with Passive Solar Design (PSD).

2. Parametric study of thermal mass property of concrete buildings in US climate zones

Amir H. Ghoreishi & Mir M. Ali

Concrete has a low thermal diffusivity, a high heat capacity, and a relatively low thermal conductivity. Therefore, this material could delay the heat transfer through a building envelope. These characteristics of concrete can make it a significant thermal mass material compared with other building materials including steel or wood.

Exposure to the sun can improve and enhance the effect of thermal mass. 20cm can be an optimal wall thickness in terms of thermal mass impact on cooling demands. For residential buildings, cold climates show a higher reduction of cooling demands due to the increase of thermal mass.

As the thermal mass increases, the cooling requirements slightly increase as well, which is not expected given the nature of thermal mass.

In conclusion, extreme conditions can better exploit the thermal mass properties of materials than milder climates. The findings discussed between office and residential occupancies, as well as the heating, cooling, and total energy consumptions (i.e. combining heating and cooling energy demands), suggest that the increase of thermal mass could generally reduce the heating and cooling requirements regardless of location and occupancy.

3. Steel Construction Info

There is a common belief that heavyweight buildings are more effective than lightweight alternatives in mobilizing optimum levels of thermal mass. This has probably arisen because buildings such as old churches and castles are cool in the summer. However, the main reason that such buildings remain cool is because they have very relatively few windows, which reduces solar gain, and are relatively lightly populated, which reduces internal gains. In modern buildings, the greatest accessible mass is found in the upper floor slabs. Independent research[1] has shown that the optimum thickness of concrete floor slab for providing thermal mass on a diurnal cycle of heating and cooling is 75 - 100mm (see right). This thickness of concrete floor slab is available in almost all steel-framed buildings.

4. **Embodied and operational carbon dioxide emissions from housing:**

A case study on the effects of thermal mass and climate change

Jacob N. Hacker, Tom P. De Saulles, Andrew J. Minson, Michael J. Holmes

The heavier weight cases all showed reduced operational CO2 emissions with the largest benefits being found for the heaviest weight considered. This was primarily due to the dynamic thermal storage provided by the thermal mass improving the energy efficiency of both heating and cooling modes of operation and also, importantly, improving the passive summertime performance, thereby delaying the point in the lifecycle at which occupants.

(See table below for housing weight data)

5. **Canadian Precast/Prestressed Concrete Institute**

Notes:

- How to incorporate thermal mass into a row (prefabricated) house?
    - Walls are the most important
    - Solid concrete floor slabs in naturally ventilated or low energy mechanically ventilated buildings where the concrete soffit is left exposed to the occupied space.
- Where to place the thermal mass (as blocks, layers, containers, etc.) within the house layout? Should it be in the floors, walls, and ceiling?

House weight depending on thermal mass material and amount: Light, Medium, Medium-Heavy, Heavy. Lighter models require AC on the long run due to overheating.

Insulated Concrete forms

Insulated Concrete panels

Required ballpark **measures** of gross floor area, gross volume, footprint area, building height and depth, description of materials, approximate **construction costs** and create **images, renderings and other relevant figures** about our design.

Good thermal mass must have high specific heat capacity and high density.

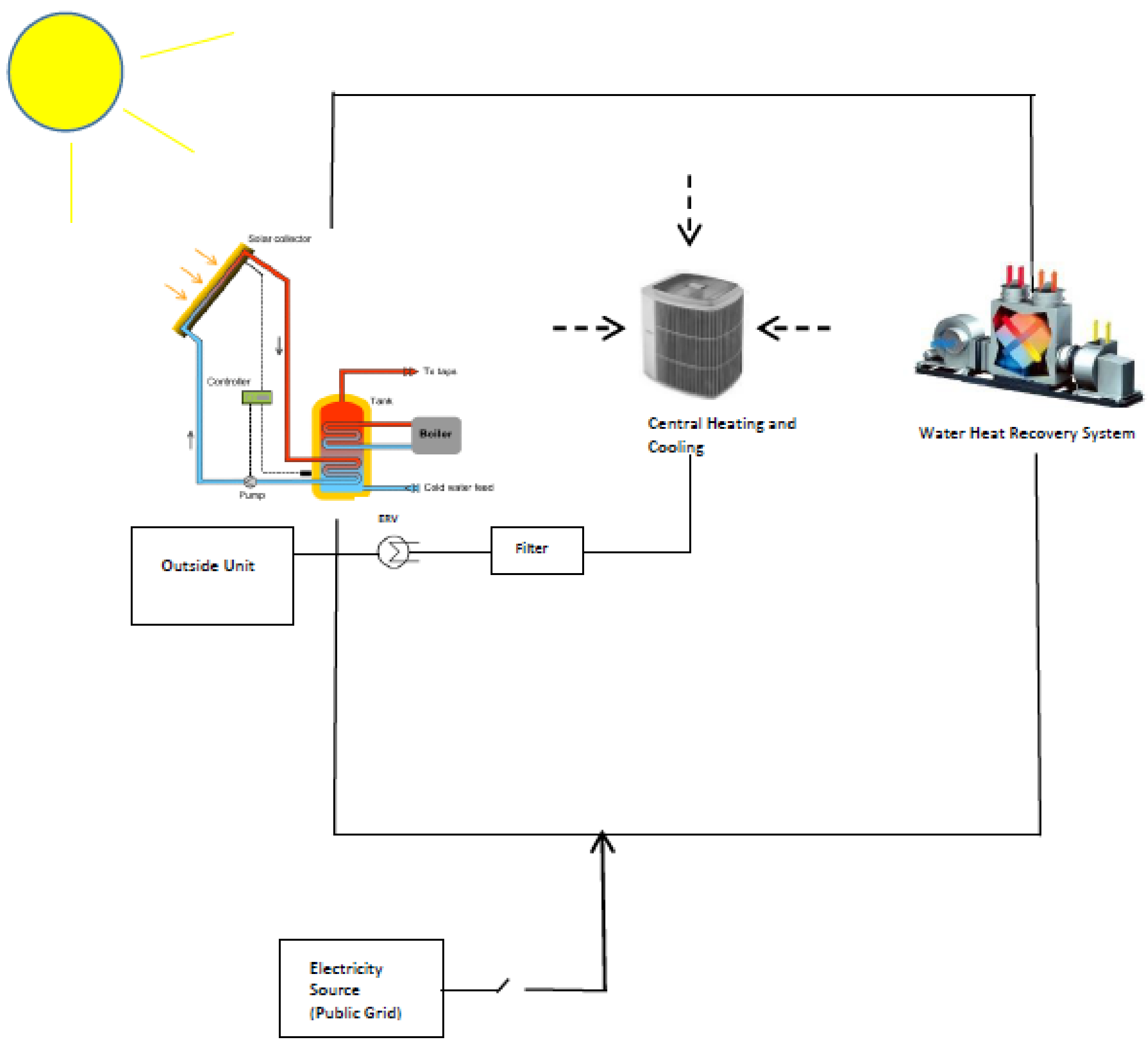
Table 2
Summary of case study building specifications

Case	Description
Lightweight	External walls: timber frame with plasterboard finish (inner leaf), insulation, ventilated cavity, brickwork cladding Internal partitions: timber stud with plaster board finish Ceilings: timber with plasterboard ceiling and chipboard floor finish Ground floor: solid concrete/screed Roof: timber/tile Flooring: carpet throughout, with exception of linoleum in bathrooms and kitchen
Mediumweight	As lightweight but with External walls: mediumweight concrete block[a] with plasterboard (inner leaf), insulation, ventilated cavity, brickwork cladding
Medium-heavyweight	As mediumweight but with Ground floor ceiling: pre-cast concrete floor units Ground floor partitions: mediumweight concrete block[a] with plasterboard finish
Heavyweight	External walls: heavyweight concrete block with fair-faced finish (inner leaf), insulation, ventilated cavity, brickwork cladding Internal partitions: heavyweight concrete block, fair-faced Ground and first floor ceilings: pre-cast concrete units Ground floor and roof construction: as other cases Flooring: carpet on first floor, with exception of linoleum in bathrooms and kitchen; stone tiles throughout ground floor

[a] In terms of admittance, mediumweight aggregate blockwork with a plasterboard finish is approximately the same as autoclaved aerated concrete (AAC) blockwork with a plaster finish [24,25]. The ECO_2 per unit volume of AAC blocks is also similar to mediumweight aggregate blocks.

Material Heat capacity	J/(g•K)
Brick	0.84
Concrete	0.88
Granite	0.79
Gypsum	1.09
Soil	0.80
Wood	1.2 - 2.3
Water	4.2

3. HVAC SCHEMATIC



4. CONCLUSION

<u>Main technologies and/or design considerations</u>

<u>Active Technologies</u>

- Heating System: Heat Pumps with electric heaters
- Solar Water Heater
- Distribution: Forced Air
- Design Consideration: Placement of Air vents for homogenous air circulation

<u>Passive Technologies (maximise as much as possible)</u>

- Phase Change Materials (PCMs)
- Thermal Heat Mass
- Desiccant/ERVs
- Heat exchangers: air to air, water to water
- Design considerations:

  (HVAC):

  - PCMs in walls and floors
  - Materials used for thermal heat mass (if visible, consider aesthetics? or hidden?)
  - Preheat water to the boiler through the solar water heater.

  (not really HVAC):

  - Roof design that allows sunlight during winter for green house effect; and shade during summer.
  - Adequate fenestration for good green house effect.
  - High insulation and triple glazed windows

Target issues

Progress

- Desiccant is an emerging technology.
- Moss filtration

People

Does not really apply to HVAC. The only relevant aspect is that the people involved in building and operation of the HVAC system will be treated well and fairly.

Planet

- Material selection: Stay away from the red list.
- Pay close attention to product life cycle. In the first part, we will choose material that are fabricated and transported in a ecological friendly manner. In second part, those material will also be chosen as a function of how they can be disposed of.
- Recycle gray water?
- Saving energy consumption through passive technologies.

Prosperity

TBD

Proficiency

- Air vents placement to have a homogeneous temperature in the house.
- Hidden air ducts
- Quiet ventilation.