There is disclosed a building energy system comprising a building enclosure having an interior and exterior. The building enclosure comprises a insulated building envelope that incorporates perimeter windows with a centre-of-glass R-value of R-4 or higher, at least one upper exhaust outlet and at least one lower supply intake that connect to the exterior of the building enclosure, and at least one central space that is connected to the lower supply intake and one or more perimeter rooms located adjacent to the central space. Each perimeter room comprises one or more lower wall vents that connect to the central space, and one or more upper vents connected to the upper exhaust outlet. The upper exhaust outlet incorporates a regulator to minimize ventilation air heat loss while maintaining indoor air quality. The regulator may comprise an automated damper and a motorized fan selectively operated based at least in part on measurements of air pollution contaminants. There is also provided a variable solar control window panel comprising coating or coatings on a number of possible glazing surfaces of a multiple glazed window. The coating or coatings comprises thin film multi-layer optical interference filters configured to selectively block solar radiation in depending upon an incidence angle of sunlight on the glazing surface.
BUILDING ENERGY SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

This invention relates generally to building energy systems and more particularly to buildings incorporating high R-value windows and simplified heating, ventilating and air conditioning (HVAC) systems.

[0002] 2. Description of the Related Art

Historically, houses were constructed without a separate ventilation system. Adequate air quality was maintained during the heating season by air entering through cracks in the basement and lower walls and exiting through cracks in the ceiling and upper walls. Generally with current energy efficient construction techniques, there is an airtight building envelope. To ensure indoor air quality there is a need for a separate, centralized mechanical ventilation system which is continuously operated. Typically, an air-to-air heat exchanger is used where the outgoing polluted air preheats the incoming outside air and this requires a centralized air distribution system. Also, it should be noted that with an air-to-air heat exchanger there is always a percentage of air that is re-circulated. When upgrading the energy efficiency and air tightness of older houses that do not have a centralized air distribution system, it is difficult to retrofit an air-to-air heat exchanger because of the extensive ductwork required. As a result, there is no major benefit in trying to achieve higher levels of air tightness.

[0003] Displacement ventilation is an alternative ventilation strategy and U.S. Pat. No. 4,935,285 discloses the advantages of combining displacement ventilation with high R-value windows. With displacement ventilation, fresh ventilation air is gradually introduced at a low level at a temperature slightly lower than room temperature. As the room occupants generate air pollutants, the polluted air slowly rises and it is then fully exhausted from the room through high level vents. Unlike conventional ventilation systems none of the polluted air is returned and re-circulated through the building and this provides for higher indoor air quality. The connection between displacement ventilation and high R-value windows is that for effective air stratification, there should be no down drafting at the windows which demands the use of high R-value windows. Typically to achieve the required air stratification, displacement ventilation is only used for buildings types that incorporate high ceilings such as auditoriums, lecture halls and classrooms.

[0004] With new house construction, it is cost effective for the building envelope to include high levels of insulation and air tightness which substantially reduces heating and air conditioning loads particularly if high performance windows (R-5 centre-of-glass or higher) are incorporated. However even with these substantially reduced energy loads, HVAC equipment costs remain comparatively high because of the need for centralized air distribution and the complexity of the heating/cooling devices required.

[0005] For high performance windows, low-emissivity (low-e) coatings are the key components. There are two main types of low-e coatings: solar control and solar gain. For a double glazed, insulating glass unit incorporating a single low-e coating, a solar control low-e coating is located on surface two and solar gain low-e coating is located on surface three where the glazing surfaces are numbered from the exterior. Comparing the two coatings, the emissivity of the solar control coating is lower resulting in reduced heat loss. However comparing solar control and solar gain windows, side-by-side test house monitoring by the National Research Council of Canada has shown that during the heating season because of higher direct solar gains, overall building energy consumption is 10 percent higher with solar gain coatings. Part of the reason that solar gain coatings provide for higher performance is that centralized mechanical ventilation systems transfer the transmitted solar gains and provide for uniform temperature conditions throughout the building. For a triple glazed unit, low-e coatings are typically located on glazing surfaces two and five with typically both coatings either being solar control low-e coatings or solar gain low-e coatings.

[0008] In order to prevent overheating with solar gain low-e coatings, south facing glazing needs to be shaded in the summer time using devices such as building overhangs or exterior awnings. As an alternative to summer shading devices, various seasonal solar products have been developed and generally, these products are special glazing sheets with complex profiles and geometries that depending on the solar angle of incidence either admit winter solar gains or block off unwanted summer solar gains.

[0009] Vacuum glazing is a new energy efficient window product that is poised for commercialization. As there is no heat loss across the small vacuum cavity through convection or conduction, the main source of glazing heat loss is through radiation. By using an ultra low-e coating radiation heat loss is reduced to a minimum and this provides for R-12 center-of-glass performance for a double-glazed unit or R-17 when the vacuum unit is incorporated into a triple-glazed unit with the second cavity space featuring low conductive inert gas fill and a second ultra low-e coating. As a result, incorporating an ultra low-e coating within the insulating glass unit, direct solar heat gains through south-facing windows are substantially reduced during the heating season. For a typical new construction house with a well insulated and airtight building envelope, direct solar gains account for at least 15 percent of the total annual space heating load. Because of the reduced direct solar contribution with high R-value vacuum windows, there is a need to develop alternative types of heating, ventilating and air-conditioning (HVAC) systems that provide additional off-setting energy savings.

SUMMARY OF THE INVENTION

[0010] In accordance with an embodiment of the present disclosure, there is provided a building energy system comprising a building enclosure having an interior and exterior. The building enclosure comprises an insulated building envelope that incorporates perimeter windows with a centre-of-glass R-value of more than R-7, at least one upper exhaust outlet and at least one lower supply intake that connect to the exterior of the building enclosure, and at least one central space that is connected to the lower supply intake and one or more perimeter rooms located adjacent to the central space. Each perimeter room comprises one or more lower wall vents that connect to the central space, and one or more upper vents connected to the upper exhaust outlet. The upper exhaust outlet incorporates a regulator to minimize ventilation air heat loss while maintaining indoor air quality.

[0011] In accordance with a further embodiment of the present disclosure, the regulator comprises an automated damper and a motorized fan that are selectively operated based at least in part on measurements of air pollutants.
[0012] In accordance with a further embodiment of the present disclosure, the lower supply intake comprises a motorized intake fan selectively controlled to provide for generally balanced air pressure conditions within said building enclosure.

[0013] In accordance with a further embodiment of the present disclosure, the building enclosure comprises two or more levels and the central space is continuous at least in part between the two or more levels.

[0014] In accordance with a further embodiment of the present disclosure, the central space comprises an open staircase.

[0015] In accordance with a further embodiment of the present disclosure, one or more upper vents is connected to the at least one upper exhaust outlet via a duct that is separated off from said central space.

[0016] In accordance with a further embodiment of the present disclosure, any of the one or more lower wall vents is a gap between a floor and a door wherein the gap connects the central space with one of the perimeter rooms.

[0017] In accordance with a further embodiment of the present disclosure, pollutants generated in any of the perimeter rooms can be vented to the exterior of the building enclosure with the assistance of separate exhaust fans that are controlled by the perimeter room occupants.

[0018] In accordance with a further embodiment of the present disclosure, a continuous piped loop, two air-to-liquid heat exchangers and a motorized pump with control system selectively preheat in-coming air at the lower supply intake using waste heat from out-going air at the upper exhaust outlet during a heating season.

[0019] In accordance with a further embodiment of the present disclosure, a continuous piped loop, an air-to-liquid heat exchanger and a motorized pump with control system selectively preheat incoming air at the lower supply intake using ground heat during a heating season.

[0020] In accordance with a further embodiment of the present disclosure, a continuous piped loop, a liquid-to-liquid heat exchanger, a hot water storage tank and a motorized pump with a control system heat ventilation air to minimum acceptable comfort temperatures during a heating season.

[0021] In accordance with a further embodiment of the present disclosure, domestic hot water is supplied from the hot water storage tank.

[0022] In accordance with a further embodiment of the present disclosure, the hot water storage tank is heated at least in part using renewable energy sources including solar thermal or biomass fuel.

[0023] In accordance with a further embodiment of the present disclosure, the hot water tank is heated at least in part using a heat recovery piped heat exchanger attached to a flue pipe of a biomass combustion device.

[0024] In accordance with a further embodiment of the present disclosure, incoming air at the lower supply intake is cooled by a seasonally stored cooling source during a cooling season.

[0025] In accordance with a further embodiment of the present disclosure, the incoming air that enters through said lower supply intake has a high relative humidity, and said high relative humidity is lowered using a dehumidifier during a cooling season.

[0026] In accordance with a further embodiment of the present disclosure, at least one of one or more perimeter rooms is heated by a radiant heat source.

[0027] In accordance with a further embodiment of the present disclosure, the radiant heat source comprises infrared light bulbs controlled by occupants of the perimeter room.

[0028] In accordance with a further embodiment of the present disclosure, the radiant heat sources comprises hydronic panels or radiators.

[0029] In accordance with a further embodiment of the present disclosure, the perimeter windows are triple glazed windows comprising three glazed substrates having an ultra low-emissivity coating on glazing surface five and a second low-e coating on either glazing surface two or three, whereby the glazing surfaces are numbered from the exterior to the interior.

[0030] In accordance with a further embodiment of the present disclosure, the emissivity of the ultra low-emissivity coating is 0.03 or less.

[0031] In accordance with a further embodiment of the present disclosure, the triple glazed windows comprise a vacuum double glazing unit located adjacent to the interior of the building enclosure.

[0032] In accordance with a further embodiment of the present disclosure, the triple glazed windows are located on a south facing elevation of a building enclosure. Use of a seasonal solar control device prevents excess solar gains during a cooling season.

[0033] In accordance with a further embodiment of the present disclosure, the triple glazed windows are rotatable such that during a heating season the ultra low-emissivity coating on glazing surface five is a solar control coating, and during a cooling season, the solar control coating is repositioned onto a renumbered glazing surface two.

[0034] In accordance with a further embodiment of the present disclosure, the perimeter windows comprise an existing single glazed window, and a removable multi-layer glazing panel having a solar control low-emissivity coating. The panel is rotatable such that the solar control coating is on surface two during a cooling season whereas said glazing surfaces are numbered from the exterior to the interior.

[0035] In accordance with a further embodiment of the present disclosure, there is provided a regulator for minimizing ventilation air heat loss while maintaining indoor air quality. The regulator comprises an automated damper and a motorized fan selectively operated based at least in part on measurements of air pollution contaminants. The ventilation air is supplied to an insulated building enclosure having windows with a center-of-glass R-value higher than R-4. The building enclosure comprises a lower supply ventilation air intake separated vertically apart from an upper exhaust ventilation air outlet. The upper exhaust ventilation air outlet incorporates the regulator.

[0036] In accordance with a further embodiment of the present disclosure, the automated damper is fabricated at least in part from low-conductive materials comprising fiberglass pulltrusions.

[0037] In accordance with a further embodiment of the present disclosure, there is provided a variable solar control window panel for a building energy system comprising a building enclosure having an interior and exterior. The panel comprises a coating on glazing surface one or two, or on surfaces one and two of an exterior glazing substrate of multiple glazed window. The coating or coatings comprises thin film multi-layer optical interference filters configured to selectively block solar radiation in depending upon an incidence angle of sunlight on the glazing surface.
In accordance with a further embodiment of the present disclosure, the coating or coatings is installed on a suitably oriented south facing window in a building enclosure located between latitudes 30 degrees and 55 degrees in the northern hemisphere.

In accordance with a further embodiment of the present disclosure, the seasonal reduction of direct solar radiation transmission substantially starts at an incidence angle of about 50 degrees and reaches a majority of required reduction at an incidence angle of about 60 degrees.

In accordance with a further embodiment of the present disclosure, the panel comprises first and second glazing substrates spaced apart and sealed around a perimeter edge. The coating or coatings is located on a glazing substrate that is adjacent to the exterior of the building enclosure. An ultra low-emissivity coating is located on a cavity face of the second glazing substrate adjacent to the interior of the building enclosure.

In accordance with a further embodiment of the present disclosure, the glazing panel comprises three glazing substrates spaced apart and sealed around a perimeter edge. The coating or coatings is located on a glazing substrate adjacent to the exterior of the building enclosure. An ultra low-emissivity coating is located on a cavity face of a glazing substrate that is located adjacent to the interior of the building enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The following is a description by way of example of certain embodiments of the present invention, reference being made to the accompanying drawings, in which:

FIG. 1 shows a second floor plan of a two story residential building incorporating a displacement ventilation system.

FIG. 2 shows a cross section on a line 1a-1c through the two story residential building as shown in FIG. 1.

FIG. 3 shows a cross section on a line 1b-1c through the two story residential building as shown in FIG. 1.

FIG. 4 shows a schematic diagram of a residential mechanical system that includes radiant heating, displacement ventilation, domestic hot water heat recovery and ground source cooling.

FIG. 5 shows a vertical centre-of-glass cross section on a line 1c-1c of a south-facing, triple-glazed, radiant window panel with a solar control coating located on surface five.

FIG. 6 shows a south-facing, triple-glazed, radiant window panel as shown in FIG. 5 and with a removable seasonal solar control device.

FIG. 7 shows a vertical centre-of-glass cross section on a line 1c-1c of a south-facing, triple-glazed, radiant window panel incorporating a vacuum insulating glass unit.

FIG. 8 shows a south-facing radiant window panel incorporating a vacuum insulating glass unit as shown in FIG. 7 and with an exterior removable seasonal solar control device.

FIG. 9 shows a vertical centre-of-glass cross sections on a line 1c-1c of a south-facing, single-glazed window and an exterior rotatable multi-glazed radiant heating panel as deployed for the heating season.

FIG. 10 shows a south facing window and exterior rotatable radiant heating panel as shown in FIG. 9 with the panel deployed for the cooling season.

FIG. 11 shows a vertical centre-of-glass cross section on line 1c-1c of a south-facing, triple-glazed, radiant window heating panel that incorporates a seasonal solar control coating.

FIG. 12 shows critical solar radiation incident angles for the Spring/Autumn swing seasons for the south-facing exterior glazing sheet as shown in FIGS. 11 and 12 with a seasonal solar control covering on surfaces one and two.

FIG. 13 shows a vertical centre-of-glass cross section on a line 1c-1c of a south-facing, double-glazed, radiant window heating panel that incorporates a seasonal solar control coating.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, FIG. 1 shows a plan of the second floor 14 of a two story building enclosure incorporating a central space 16 and perimeter rooms 17. The building enclosure 15 is typically a residential building although other building types with similar floor plans are also appropriate with the key requirement being a centralized circulation space. Surrounding the building enclosure is a building envelope 18 that incorporates an air barrier 19. The building envelope 18 consists of insulated external walls 20, insulated roof (not shown) and insulated basement walls (not shown). Perimeter windows 21 are incorporated within the insulated external walls 20. Depending on the winter design temperature conditions, the insulation R-value of the insulating external walls 20 is R-7 minimum and preferably R-20 or higher. Depending on the winter design temperature conditions and whether double or triple glazing is required to prevent down-drafting, the center-of-glass R-value of the exterior windows 21 is R-4 minimum and preferably R-7 or higher for the south facing elevation 25 and R-5 minimum and preferably R-10 or higher for the east 22, west 23, and north facing 24 elevations. On the south facing elevation 25, the perimeter windows 21 incorporate some form of solar shading device (not shown). It should be noted that these orientation references assume that the house is located in the northern hemisphere. For buildings located in the southern hemisphere, these references need to be reversed.

Common walls 26 and 27 are positioned between the central space 16 and the perimeter rooms 17. Located within the central space 16 is an open staircase 28 that links the upper two levels of the building enclosure 15. Operable doors 30 are positioned between the central space 16 and the perimeter rooms 17. Lower vents 29 (not shown) are located in the common walls 26 and 27 between the perimeter rooms 17 and the central space 16. Alternatively, instead of lower vents 29, the gaps 73 between the bottom of the operable doors and the floor can function as the lower vents 29 (See FIG. 3). Upper vents 42 (See FIG. 2) are positioned horizontally apart from the lower vent 29 and connect to vertical exhaust ducts 33, 34, 35 that are located on the perimeter room sides 31 and 32 of the common walls 26 and 27. The vertical exhaust ducts 33, 34, 35 connect to an exhaust air outlet 70 that is positioned centrally above the open staircase 28 and is shown on the building plan by a dotted line 38. As shown by arrows 37, fresh ventilation air is supplied to the perimeter rooms 17 via the open staircase 28. Fresh air is supplied to the lower level of the central space 16 through a major ar duct 48 and a supply air inlet 46 (See FIG. 2).

As a supplementary means to ensure high air quality, major air pollutants generated in a specific location are
directly vented to the exterior by means of separate exhaust fans 50 that are directly controlled by the room occupants. Typically, the operation of the separate exhaust fans 50 are time controlled to help ensure that ventilation air heat loss is kept to a minimum.

**[0059]** FIG. 2 shows a cross section on a line 1a-1a through a two story building enclosure shown in FIG. 1. Fresh air is supplied to the lower level of the central space 16 through a major air duct 48 and supply air inlet 46. Vertical ducts 33, 34, 35 (see FIG. 1), respectively connect the basement 40, the first floor 29 and the second floor 14 to the exhaust outlet 36 via a dropped ceiling duct space 41 that is located between the two common walls 26 and 27 and separated off from the central space 16. For each perimeter room 17, ventilation supply air 37 enters through the lower vents (not shown) at a low velocity and at a temperature only slightly below the desired room temperature. The cooler supply air displaces the warmer room air creating a zone of fresh air at the occupied level. Heat and contaminants (shown by arrow 74) produced by the room occupants and their activities rise to the ceiling 75. The polluted air as shown by arrows 44 is then fully exhausted from the perimeter room 16 through the upper vents 42.

**[0060]** The cross section line 1a-1a specifically shows the vertical duct 33 from the basement level 40 and the vertical duct 34 from the first floor level 29. By installing vertical ducts 33, 34, 35, the polluted air 44 from the perimeter rooms 17 does not contaminate the fresh air supply 37. The incoming air 45 from the supply air inlet 46 is fed to a lower point 47 of the central space 16 by means of a major supply duct 48. The incoming air 45 is preheated by means of a liquid-to-air heat exchanger 49 that is joined to ground buried pipes 52 to form a continuous piped loop 53.

**[0061]** By circulating a heat transfer liquid such as glycol through the liquid-to-air heat exchanger 49, the incoming ventilation air 45 is preheated and by using glycol, there is no concern that the heat transfer liquid will freeze in cold temperatures. The incoming ventilation air 45 is further preheated by means of a second liquid-to-air heat exchanger 54 that is joined through a continuous piped loop 55 to a heat recovery liquid-to-air heat exchanger 56 located within the duct space 41 above the dropped ceiling 39.

**[0062]** The incoming air is further heated as required to comfort temperatures by means of a third liquid-to-air heat exchanger 57 that then is connected to a complementary liquid-to-liquid heat exchanger 58 located within the hot water storage tank 59. Preferably, the hot water tank 59 is heated by means of renewable energy sources including solar thermal collectors 60 located on the roof 61 and/or by means of a heat recovery piped heat exchanger 62 attached to the flue pipe of a biomass combustion device 64. As a back-up heating source, a conventional electric hot-water heater 65 can be used or alternatively, a conventional hydronic boiler can be used connected to a liquid-to-liquid heat exchanger (not shown). Generally, very limited use of conventional energy sources is required for pre-heating the ventilation air and as previously described, this is because full advantage is taken of heat recovery and renewable energy sources, and also because the incoming air only has to be pre-heated to minimum acceptable comfort temperatures.

**[0063]** Through buoyancy and stack effects, the incoming ventilation supply air shown by arrows 37 rises through the building and is exhausted through the exhaust outlet 36. Particularly during the cold winter months when there is a large temperature difference between the incoming and outgoing air, the ventilation stack effect is considerable and there is no need for mechanical fans to provide for adequate ventilation air supply within the perimeter rooms 17. Particularly when the building is unoccupied, ventilation air heat loss though the exhaust outlet 36 can be excessively high and a regulator 71 is used to reduce ventilation heat loss. The regulator 71 incorporates an automated damper 66 that is selectively controlled based on a number of factors, including occupancy, outside air temperatures and direct measurement of air pollution contaminants. Because there is no re-circulation of contaminated air and because air is stratified within the perimeter rooms, pollutant levels can build-up sufficiently so that measurement sensors can be used to determine unacceptable pollution levels. Different air contaminants can be evaluated including: relative humidity and carbon dioxide concentration.

**[0064]** To help prevent conductive heat loss when the damper blades 71 are in a closed position, the automated damper 66 is fabricated at least in part form low conductive material with one preferred low-conductivity material being fiber-glass pulltrusions.

**[0065]** Particularly in the swing seasons, natural ventilation is not sufficient to provide for adequate air quality and the regulator 71 also incorporates a motorized blower or fan 67 that can be selectively operated to provide for higher ventilation levels. As with the automated damper 66 the operation of the motorized fan 67 is also selectively controlled based on direct measurement of air pollution contaminants.

**[0066]** To provide for generally balanced air pressure conditions within the building enclosure 15, a second motorized fan 68 is used in tandem with the first motorized fan 67 and this second supply air fan 68 is located within the supply air inlet 46. The operation of the supply air fan 68 is also selectively controlled to at least partially replenish the air that is removed from the building through other means than the main exhaust fan 67. These other means include separate occupant-controlled exhaust fans; major appliances such as clothes dryers and vented air from biomass combustion devices.

**[0067]** With a highly insulated building envelope and preheated ventilation air, comfortable room temperatures can generally be maintained without the constant need for supplemental heating. Depending on the activities to be carried out, room temperatures in select locations can quickly be adjusted to higher comfort conditions using fast response infrared (IR) light bulbs 71 or IR mirror panels (not shown). Both IR light bulbs and IR mirrors use electricity that is generally more expensive than other energy sources but if the radiant heaters are only selectively used for short periods of time, the higher electrical costs can be justified.

**[0068]** For existing building retrofit applications where there is a need for higher levels of supplemental heating, conventional radiant sources can be used including hydronic radiators and biomass combustion devices. Compared to ducted air distribution, hydronic distribution systems offer a number of advantages, including: reduced energy required for heat transfer; simplified room-by-room zoning and the option of a single high-efficiency condensing boiler providing both for space and domestic hot water heating. For biomass combustion devices, one key advantage is that these devices 64 offer the traditional appeal and romance of a burning fire. Generally, biomass fuel is a convenient way of storing solar energy from the peak summer months and using this stored energy in the winter when there is only limited solar energy available. Different types of combustion devices can be used, including: both traditional wood stoves and
bio-pellet stoves that incorporate automatic ignition systems for conventional thermostat control.  

[0069] During the swing Spring and Fall seasons when no space heating or cooling is required, ventilation air can be provided through opening perimeter windows 21.  

[0070] For summer operation, the incoming air 45 is first cooled by the first liquid-to-air heat exchanger 49 that is jointed to the ground buried pipes 52 in a continuous piped loop 53.  

[0071] The incoming ventilation air 45 can be further cooled by the third liquid-to-air heat exchanger 57 that is joined to a seasonal cooling source (not shown). Various seasonal cooling sources can be used including: ground water and stored winter ice/snow.  

[0072] FIG. 3 shows a cross section on a line 15-16 through a two story building enclosure 15 shown in FIG. 1. Specifically FIG. 3 shows a cross-section through the central space 16 and the perimeter rooms 17. Fresh ventilation air as shown by arrows 37 enters the perimeter rooms 17 from the central space 16 through gaps 73 beneath the operable doors 30. Typically, the height of the gaps 73 is a minimum of ½ inch and is preferably % inch or more. As previously described, heat and contaminants (shown by arrow 74) produced by the room occupants and their activities rise to the ceiling 75. The polluted air as shown by arrows 44 is then fully exhausted from the perimeter rooms 17 through the vents 42 (not shown).  

[0073] FIG. 4 shows a system schematic of the heating, ventilating and air conditioning (HVAC) system for a two-story building enclosure 15. The HVAC system consists of the following major components: supply air unit 48, exhaust air unit 70, ground buried piping system 57, seasonal cooling system 76, drain water heat recovery 77, flue pipe heat recovery 63, solar water heating system 60, hot water tank storage 59 and supplementary heating system 93.  

[0074] The supply air unit 48 is a continuous duct that incorporates: a supply air inlet 46, a motorized fan 65 located adjacent to the supply air inlet 46, a first liquid-to-air heat exchanger 49 that preheats or cools the incoming air 45 and is connected to the ground buried piping system 52; a second liquid-to-air heat exchanger 54 that during the heating season further preheats the incoming air and is connected to a liquid-to-air heat exchanger 58 located within the exhaust unit 70; a third liquid-to-air heat exchanger 57 that during the heating season is connected to a liquid-to-liquid heat exchanger 58 located within the hot water storage tank 59, or during the cooling season is connected to the seasonal cooling system 76 and an outlet sensor 78 that measures outdoor air temperatures and accordingly controls the operations of a pump 78 to heat or cool the outgoing air 79 to the required minimum comfort temperature.  

[0075] The exhaust air unit 70 is connected to vertical exhaust air ducts 33, 34 and 35 as indicated by the arrow 80. A liquid-to-air heat exchanger 56 is located within the duct space 41 that is typically located above an open staircase 28. A motorized exhaust fan 67 in the exhaust outlet 81 removes the polluted air from the building enclosure 15; an automated damper 66 regulates the outgoing flow of air through the exhaust outlet 81 as shown by arrow 82. Both the operation of the automated damper 66 and the exhaust fan 67 are regulated based on measurements of air quality by sensor 69. In combination, the automated damper 66, the motorized exhaust fan 67, air quality sensors 69 and controller function as a control means 89 for regulating air quality within the building enclosure 15. A pump 83 transfers heat from the exhaust air heat exchanger 56 to the second supply air heat exchanger 54 and by means of temperature sensors and a controller (not shown), the pump 83 is only operated when waste heat can be usefully collected.  

[0076] The ground buried piping system 52 consists of a continuous length of piping buried in the ground. Depending on the local climate conditions, the piping needs to be buried at least 4 feet below the surface. Standard flexible high temperature polyethylene piping 85 can be used with the piping buried within a layer of sand to ensure good thermal contact with the ground. A pump 84 transfers heat or cooling from the ground to the first supply air heat exchanger 49 and by means of temperature sensors and controller (not shown), the pump 84 is only operated when useful ground heat or cooling can be supplied.  

[0077] Because the temperature of the incoming ventilation air only has to be lowered to just below 20° C, there is significant potential for using seasonal cooling storage for buildings located in cold climate locations. Depending on local conditions, the seasonal cooling storage system 76 can utilize various seasonal storage options including winter storage of ice and snow. Where available, one preferred option is the use of ground water. As shown in FIG. 4, the seasonal cooling system consists of a disused well 90 and a storage tank 91. After the cooling water has passed through the third supply air heat exchanger 57 the ground water is moved to the tank 91 where the ground water can be later usefully used for applications such as garden watering. By means of temperature sensors and controller (not shown), the pump 92 only operates when useful ground water cooling can be supplied.  

[0078] The drain water heat recovery system 77 requires that warm waste water from showers and sinks is separated from cold toilet water. One suitable commercially available product is Power Pipe™ manufactured by RenewABILITY of Waterloo, Ontario. It consists of a straight length of copper pipe 94 incorporated within the main plumbing stack 95 with a spiral loop of copper water pipe 96 bonded to the outside of the main copper pipe 94. Cold water from the well or water mains flows through the spiral 96 and picks up heat from the metal wall of the drain pipe 96. The lukewarm water is either directly supplied to the hot water tank 59, or directly used as a warm water supply for showers, laundry etc. In comparison with the present system, the warm water temperature is increased by mixing with hot water as to oppose to conventional practice where hot water is cooled down by mixing with cold water.  

[0079] The flue pipe heat recovery system 63 recovers waste heat from the combustion by products from a biomass combustion device such as a wood stove. It also consists of a straight length of flue pipe 97 with a spiral loop of copper water piping 98 bonded to the outside of the flue pipe 99. Cold water from the well or water main 100 flows through the spiral loop 98 and picks up heat from the metal wall pipe 97. By means of a pump 101, the waste heat from the flue pipe 99 is then transferred to the hot water storage tank 59 and temperature sensors and controller (not shown) ensures that the pump 101 only operates when useful recovered heat can be supplied. The control system is also set up to ensure that excessively cold water is not circulated through the spiral loop 98 as this could cause problems of creosote build-up.  

[0080] The solar hot water heating system 60 consists of an array of solar collectors 102, a pump 103, a drain back tank 104, and a control system (not shown). When the pump 103 is
not operating, the water drains back to the tank 104 protecting the collectors 102 from either high temperature stagnation or freezing conditions.

The hot water storage system 59 consists of an insulated tank 104. The water in the tank 104 is heated preferably by renewable energy sources and as shown in FIG. 4, the water is heated by means of a liquid-to-liquid heat exchangers 106 and 107 that are respectively connected to solar water heating systems 60 or the flue pipe heat recovery system 63 for a biomass combustion device. Cold water from a well or piped water system is also preheated by means of a drain water heat recovery system 77. Advantage is taken of the thermal stratification within the tank 104 to supply extra hot water for clothes washing, dish washing etc. As shown in FIG. 4, the hot water tank 105 incorporates a conventional electrical heater 108 as a back-up heating source or alternatively, the hot water tank can be heated by a liquid-to-liquid heat exchanger (not shown) linked to a conventional boiler (not shown) that could also supply hot water for a conventional radiator space heating system. Typically, a conventional hot water radiator system is only required for retrofit applications. As shown in FIG. 4, for an air tight, well insulated house, the radiant space heating system can simply consist of a series of infra-red light bulbs 109 that are individually controlled.

The HVAC system shown in FIG. 4 is designed for a heating dominated climate such as Canada where because of the extended cold winter, ground source cooling is feasible. In a cooling dominated climate such as the southern United States, residential displacement ventilation also offers advantages but modifications are required in the HVAC system design. Particularly in high humidity climates, removing moisture from ventilation air accounts for than 50 percent of the cooling load. To selectively remove moisture from the ventilation air, a dehumidifier 88 can be incorporated into the air supply unit 48. The preferred type of dehumidifier is a liquid desiccant dryer that is used in combination with the solar thermal system 60 that reactivates the liquid desiccant material during the summer months. In hot dry desert climates, the incoming air can be cooled down by means of a cold water moisture spray (not shown) with the resulting humidity then removed by means of the dehumidifier 88. As required, the incoming air can further cooled down by means of a heat exchanger linked to conventional heat pump. Because of the reduced cooling load, one preferred option is to use a small heat pump for both space cooling and food refrigeration.

In cooling dominated climate, the main advantage of displacement ventilation is that because there is no air re-circulation and all interior generated humidity and heat is efficiently exhausted, substantially less ventilation fan power is required. By lowering humidity levels and eliminating potential condensation problems, simple radiant cooling devices such as radiator panels are sufficient to provide cooling comfort conditions. Also there is no need for triple glazed units and only solar control low-e double glazed units (R-5) are required to eliminate window down drafting during the mild winter months.

FIG. 5 shows a cross section detail on a line 1c-1c through a south facing window 116 incorporating an insulating triple glazed unit 117. Comprised of three glazing sheets 127, 126, and 129, the triple glazed unit 117 incorporates low-e coatings on surface five 118 and surface two 119 where the glazing surfaces are numbered starting with the exterior glazing surface 120. In contrast to conventional practice, a solar control, low-e coating 121 is located on surface five 118 and a solar gain coating 122 is on surface two 119. The solar control, low-e coating 121 on surface five 118 is spectrally selective allowing for high transmission of visible light and very limited transmission of ultra violet and near infrared radiation. One preferred coating product is manufactured by Cardinal Industries and is trade named LoE3 with the reference to three indicating that the coating incorporates three thin film silver layers. A solar gain low-e coating 122 is located on surface two 119 or three 130 and the solar gain coating 122 is typically either a sputtered coating that incorporates a single thin film layer or a doped oxide coating that is directly applied to the glass substrate during the float glass production process. The insulating glass unit 117 incorporates cavities 123 and 124 and to reduce conductive heat loss, these cavities are typically filled with an inert gas such as argon.

With a solar gain, low-e coating on surface five (not shown) near infra-red solar heat is directly transferred to the building interior and is then absorbed by various surface materials before being quickly transferred to the room air creating strong convective air flow movement within the perimeter room. As a result, the air stratification required for effective displacement ventilation is disturbed so that contaminated polluted air is not so efficiently removed from the room.

In contrast with a solar control low-e coating 121 on surface five 118, heat is transferred to the room primarily through radiation and as a result, air stratification is not substantially disturbed. The combination of triple glazing and two low-e coatings ensures minimum heat loss and even when there is no solar gain, interior glass temperatures are very close to room temperatures and so there is no down drafting at the windows 116. By locating the solar control low-e coating 121 on surface five 118 of the insulating glass unit 117, infra-red (IR) light bulbs can be directed at the window 116 causing the glass interior 127 to quickly heat up so that the window 116 can act as radiant heating panel within the room 17. If necessary when there are very extreme exterior temperatures, IR light bulbs can be used to maintain the interior glass 127 above room temperatures and prevent any down drafting at the windows 116.

To limit conductive heat loss at the perimeter edge, the insulating glass unit incorporates an insulating edge seal (not shown) that is made at least in part from low conductive materials. In order to accommodate differential glass expansion and glass bowing, the edge seal materials also have to be flexible. Various alternative edge seals can be used and one preferred configuration consists of a flexible desiccant-filled, foam spacer backed up by low permeable sealant material. One suitable flexible desiccant-filled, foam spacer is manufactured by Edgetech IG Inc. of Cambridge, Ohio and is marketed under the trade name of SuperSpace™.

Under sunny conditions, the solar control low-e coating 121 blocks the near infra red solar radiation shown by dotted line 132 causing the interior glazing sheet 127 to heat up. The absorbed solar heat is then transferred to the interior building primarly through radiation as shown by arrows 136. Although heat flow is strongly driven by temperature differential and despite the colder exterior temperatures, more absorbed solar heat is transferred to the building interior 132 than to the outside 135 due to five main factors: (1) the ultra low-e coating substantially reduces radiation heat loss
across the warm side cavity 123; (ii) the solar gain low-e coating 122 reduces radiation heat loss across the cold side cavity 124; (iii) the inert gas fill prevents conductive gas across cavities 123 and 124; (iv) the widths of cavities 123, 124 are optimized to prevent convective/conductive heat loss, and (v) the insulating edge seals (not shown) help prevent perimeter edge heat loss.

[0089] Typically by coating a solar control low-e coating on surface five 118, there is excessive heat build-up within the insulating glass unit 117 and this can result in premature edge seal failure due to a combination of glass bowing and differential thermal expansion between glass sheets 127, 128, and 129. However this problem of premature edge seal failure can be eliminated by incorporating flexible perimeter edge seals that accommodate the increased glass movement due to higher cavity temperatures.

[0090] FIG. 6 shows a cross section detail of the south-facing window 116 shown in FIG. 5 during the cooling season. An exterior shading device 137 is used to prevent direct solar radiation 114 from hitting the window 116. Various shading devices can be used, including canvas awnings, overhangs, exterior shutters, etc. Generally, canvas awnings are very effective for the homeowner, but there is the inconvenience of installing and removing these devices every year.

[0091] FIG. 7 shows an alternative cross section detail on a line 1c-1c through a south facing window 116 that incorporates a vacuum double glazed unit 133 and an exterior glazing sheet 129. The vacuum unit incorporates an ultra low-e coating 121 on surface five 118. The glazing sheets 127 and 128 are separated by non-conductive spacers (not shown) and because these spacers are very small, there is limited conductive heat loss between the glazing sheets 127 and 128. By creating a vacuum between the two glazing sheets, 127 and 128, there is essentially no heat loss by conduction or convection and by incorporating an ultralow emissivity coating 121, radiation heat loss is also kept to a minimum. As a result, once the interior glazing sheet 127 is heated by means of solar radiation, most of this heat is eventually transferred to the building’s interior 134. To optimize solar heat gain, it is preferred that the low-e coating on surface two 119 of the insulating glass unit is a solar gain low-e coating 122 but the resulting higher solar gain accentuates problems of differential expansion and glass stress. A solar control low-e coating can be substituted but this results in a reduction of useful solar heat gains.

[0092] FIG. 8 shows a cross section detail of the south-facing window 116 shown in FIG. 7 during the cooling season. It is important if a solar gain low-e coating 122 is used on surface two that an exterior solar shading device 137 is used to prevent excessive solar gains. As previously discussed, one preferred shading device is a removable canvas awning.

[0093] FIG. 9 shows a second alternative cross section detail on a line 1c-1c through a south facing window assembly 139 comprising a single glazing window 140 and an outer removable glazing panel 141 that can be rotated as required. The removable panel 141 incorporates an insulating multi-glazing sealed unit 142 installed within a perimeter frame (not shown). The insulating, multi-glazing sealed unit 142 comprises two outer glass sheets 127 and 129 and two flexible inner plastic glazing films 143 and 144. The key advantage of using flexible films 143, 144 is that the weight of the removable panel 141 is reduced but the use of flexible films does complicate the unit manufacturing process. Typically to prevent film wrinkling, the plastic films 143 and 144 are heat tensioned and are firmly held in place at the perimeter edge seal (not shown). A solar control ultra low-e coating 121 is applied to a cavity surface 145 of one of the glass sheets 127 or 129 and solar gain coatings 122 are applied to a single surface 146 of the flexible films 143 and 144.

[0094] During the heating season, the solar control low-e coating 121 is located on the cavity surface 145 of the glazing sheet 127 adjacent to the single glazaded window 140. As indicated by the dotted line 132, near-infra-red radiation is absorbed by the glazing sheet 127 and then redirected to the building interior 134 as shown by dotted arrows 136. Although the additional single glazed window 140 limits the amount of heat transferred to the building interior 134, the removable panel 141 ensures that the interior glazing 147 is kept sufficiently warm, and that there is no down drafting at the windows particularly during daylight hours when the curtains are typically open.

[0095] As shown in FIG. 10 during the cooling season, the panel 141 is removed and rotated so that the control low-e coating 121 is on surface two 119 of the window assembly 139. As a result of relocating the position of the solar control, low-e coating 121, excess solar gains, as shown by arrows 150, can be rejected without the need for exterior shading devices. Typically, the use of removable panels is limited to heritage buildings where there is a need to improve energy efficiency without replacing the existing single glazed heritage sash frame. For conventional windows, the same concept of a rotating panel can also be used except that typically the entire sash frame is removed, rotated and then replaced within the window frame.

[0096] FIG. 11 shows a third alternative cross section detail on a line 1c-1c through a south facing window 116 incorporating an insulating triple glazed unit 117. Comprised of three glazing sheets, 127, 128, and 129, the triple glazed unit 117 incorporates a solar control low-e coating 121 on glazing surface five 118 and a solar gain low-e coating 122 on glazing surface two 119 or glazing surface three 130 where the glazing surfaces are numbered from the exterior. To eliminate the need to either install and remove an exterior solar shading device (e.g. canvas awnings) or rotate the window panel on a seasonal basis, the unit 117 incorporates a variable solar control coating 152 located on surface one 129 or surface two 119, or on both surfaces one 120 and two 119. The coating or coatings are in the form of optical thin film interference filters that are configured to selectively block the near infra-red solar radiation 133 shown by dotted line in dependence on the incidence angle of the sunlight on the exterior glazing sheet 129.

[0097] The seasonal solar control coating 152 is similar to anti-counterfeit features on Canadian bank notes where light is selectively reflected depending on the angle of incidence. In the case of anti-counterfeit layers, the coating is designed to change color as the bank note is rotated back and forth. In the case of a window, the coating 152 is fixed in position and the angle of sunlight varies depending on the time of the year. In the winter, the sun 153 is low on the horizon and the near infra-red solar radiation 132 passes through the seasonal solar control coating 152 so that it reaches the solar control ultra low-e emissivity coating 121. The interior glazing sheet 127 heats and solar heat is then transferred to the room interior as shown by arrows 115. In the summer, the sun 154 is high on the horizon and the near infra-red radiation 132 is reflected by
the seasonal solar control coating 152 and so the solar radiation 132 does not reach the solar control, ultra low-e emissivity coating 121.

Various combinations of different materials and number of thin film layers can be used to achieve required variable solar control performance. Typically to achieve the required sharp cut-off, a minimum of twelve thin film coating layers is required. Given the present limitations of thin film sputtering equipment, one preferred design is to incorporate six layer coatings 155, 156 on both surfaces 119, 120 of the exterior glazing substrate 129. Preferably, the multi-layer coating 156 on surface one 120 also functions as a water sheeting coating to reduce the need for glass cleaning and the multi-layer coating 155 on surface two 119 also functions as a second low-e coating to reduce radiation heat transfer across the outer cavity 124. The key advantage of applying twin multi-layer coatings 155, 156 to the exterior glazing substrate 129 is that a twelve layer composite assembly can be achieved in one production pass. Also, by incorporating coatings on either side of the exterior glass substrate 129, the refractive properties of the glass substrate 129 can also be employed in the design of the variable solar control coatings 155, 156.

As with the anti-counterfeiting coatings used for bank notes, the materials used for the thin film layers of the exterior coating 156 must be durable under long term exposure conditions while the materials used for the thin film layers of the inner coating 155 need not be so durable and there is the option of incorporating a metallic layer that has low emissivity properties like silver. In addition, the thin film layers must also be transparent and not create any visual distortions or color effects.

In the mid northern latitudes, including the heavily populated regions of Canada, the seasonal solar control coating 152 provides some useful solar gains during the long heating season and reduces excessive solar gains in the short cooling season. As well by incorporating an ultra low-e coating 121 on surface five and a solar gain low-e coating 122 on surfaces two or three, the high performance (R-10) triple glazed unit 117 substantially reduces heat loss and also facilitates the use of displacement ventilation by eliminating window down-drafting under extreme cold weather conditions.

FIG. 12 shows a cross section detail of the exterior glass sheet 129 shown in FIG. 11 that incorporates twin seasonal solar control coatings 155 and 156 on surfaces one 119 and two 120. To determine the optimum cut-off angle, a sun path study was carried out for a Toronto location, the study showed that in order to ensure that most of the useful winter solar gains are captured, the seasonal solar control coatings 155, 156 should start to reject to solar radiation at an incidence angle 158 of about 50 degrees to the normal 159 and reach the majority of the required reduction of transmitted solar radiation at an incidence angle 160 of about 60 degrees to the normal 159. Of interest, the study also showed that the same optimum cut-off angles for Toronto (43 degrees) are generally appropriate for southern US locations such as Atlanta (53 degrees) and are also appropriate for more northerly locations up to about latitude 55 degrees. Beyond latitude 55 degrees, the sun remains too low on the horizon during the summer months for variable control solar coatings to be effective but in these high northern latitudes, there is generally no need for solar control coatings as the buildings are not air conditioned.

Generally, one optimum cut off angle is suitable for most of the well populated regions of North America. This is because the closer a building is located to the equator, the higher the sun is in the sky and so the shorter the solar gain period in the winter. At the same time, the closer a building is located to the equator, the warmer the weather and the shorter the heating season. Similarly, the further away a building is from the equator, the lower the sun is in the sky and so the longer the solar gain period in the winter. At the same time, the further away a building is from the equator, the colder the weather and the longer the heating season. As a result of these offsetting factors, essentially the same variable solar control coating product can be used throughout North America and so this provides for economies of scale when manufacturing the complex, multi layer coating. Although optimized for windows oriented to the south, the variable solar control coating is generally effective for orientations ranging from the south east to the south west.

FIG. 13 shows a cross section of a double-glazed unit 161 incorporating a seasonal solar control coatings 155 and 156 located on glazing surfaces one 119 and two 120 a low-e coating 121 located on surface three 130. In the winter, the near infra red solar radiation 132 passes through the seasonal solar control coating while in the summer, the near infra red solar radiation 132 is reflected. For the mid southern latitudes, including the southern United States, the advantage of the seasonal solar control coating 152 is that it substantially reduces solar gains from about 30% for a solar control coating to about 10% during the long cooling season and at the same time provides some useful solar gains during the short heating season. As well by incorporating an ultra low emissivity coating 121 on surface three, the R-5 double glazed unit 161 reduces winter heat loss and also facilitates the use of displacement ventilation by eliminating window down drafting under moderate cold weather conditions.

Numerous modifications, variations and adaptations may be made to the particular embodiments of the invention described above without departing from the scope of the invention which is defined in the claims.

What is claimed is:

1. A building energy system comprising:
   a building enclosure having an interior and exterior, and comprising:
   an insulated building envelope that incorporates perimeter windows with a centre-of-glass R-value of R-4 or higher;
   at least one upper exhaust outlet and at least one lower supply intake that connects to the exterior of the building enclosure; and
   at least one central space that is connected to said lower supply intake and one or more perimeter rooms located adjacent to said central space, wherein each of said perimeter room comprises:
   one or more lower wall vents that connect to said central space; and
   one or more upper vents connected to said upper exhaust outlet, wherein said upper exhaust outlet incorporates a regulator to minimize ventilation air heat loss while maintaining indoor air quality.

2. The building energy system of claim 1 wherein said regulator comprises an automated damper and a motorized fan that are selectively operated based at least in part on measurements of air pollutants.

3. The building energy system of claim 1 wherein said lower supply intake comprises a motorized intake fan selec-
tively controlled to provide for generally balanced air pressure conditions within said building enclosure.

4. The building energy system of claim 1 wherein said building enclosure comprises two or more levels and wherein said central space is continuous at least in part between said two or more levels.

5. The building energy system of claim 4 wherein said central space comprises an open staircase.

6. The building energy system of claim 1 wherein one or more upper vents is connected to said at least one upper exhaust outlet via a duct that is separated off from said central space.

7. The building energy system of claim 1 wherein any of said one or more lower wall vents is a gap between a floor and a door wherein said gap connects said central space with one of said perimeter rooms.

8. The building energy system of claim 1 wherein pollutants generated in any of said perimeter rooms can be vented to the exterior of the building enclosure with the assistance of separate exhaust fans that are controlled by occupants of said perimeter rooms.

9. The building energy system of claim 1 wherein during a heating season a continuous piped loop, two air-to-liquid heat exchangers and a motorized pump with control system selectively pre-heat in-coming air at the lower supply intake using waste heat from out-going air at the upper exhaust outlet.

10. The building energy system of claim 1 wherein during a heating season, a continuous piped loop, an air-to-liquid heat exchanger and a motorized pump with control system selectively preheat incoming air at the lower supply intake using ground heat.

11. The building energy system of claim 1 wherein during a heating season, a continuous piped loop, a liquid-to-liquid heat exchanger, a hot water storage tank and a motorized pump with a control system heat ventilation air to minimum acceptable comfort temperatures.

12. The building energy system of claim 11 wherein domestic hot water is supplied from said hot water storage tank.

13. The building energy system of claim 11 wherein said hot water storage tank is heated at least in part using renewable energy sources including solar thermal or biomass fuel.

14. The building energy system of claim 11 wherein said hot water tank is heated at least in part using a heat recovery piped heat exchanger attached to a flue pipe of a biomass combustion device.

15. The building energy system of claim 1 wherein during a cooling season, incoming air at the lower supply intake is cooled by a seasonally stored cooling source.

16. The building energy system of claim 15 wherein during a cooling season, the incoming air that enters through said lower supply intake has a high relative humidity, and said high relative humidity is lowered using a dehumidifier.

17. The building energy system of claim 1 wherein at least one of one or more perimeter rooms is heated by a radiant heat source.

18. The building energy system of claim 17 wherein said radiant heat source comprises infrared light bulbs controlled by occupants of said perimeter room.

19. The building energy system of claim 17 wherein said radiant heat sources comprises hydronic panels or radiators.

20. The building energy system of claim 1 wherein said perimeter windows are triple glazed windows comprising three glazed substrates having an ultra low-emissivity coating on glazing surface five, and a second low-e coating on either glazing surface two or three, whereby said glazing surfaces are numbered from the exterior to the interior.

21. The building energy system of claim 20 wherein the emissivity of said ultra low-emissivity coating is 0.03 or less.

22. The building energy system of claim 20 wherein said triple glazed windows comprise a vacuum double glazed unit located adjacent to the interior of said building enclosure.

23. The building energy system of claim 20 wherein said triple glazed windows are located on a south facing elevation of a building enclosure and wherein use of a seasonal solar control device prevents excess solar gains during a cooling season.

24. The building energy system of claim 20 wherein said triple glazed windows are rotatable such that: during a heating season said ultra low-emissivity coating on glazing surface five is a solar control coating; and during a cooling season, said solar control coating is repositioned onto a renumbered glazing surface two.

25. The building energy system of claim 1 wherein said perimeter windows comprise: an existing single glazed window; and a removable multi-layer glazing panel having a solar control low-emissivity coating wherein said panel is rotatable such that said solar control coating is on surface two during a cooling season whereby said glazing surfaces are numbered from the exterior to the interior.

26. A regulator for minimizing ventilation air heat loss while maintaining indoor air quality, wherein said regulator comprises an automated damper and a motorized fan selectively operated based at least in part on measurements of air pollution contaminants, and whereby:

said ventilation air is supplied to an insulated building enclosure having windows with a center-of-glass R-value of R=4 or higher;

said building enclosure comprises a lower supply ventilation air intake separated vertically apart from an upper exhaust ventilation air outlet; and

said upper exhaust ventilation air outlet incorporates said regulator.

27. The regulator of claim 26 wherein said automated damper is fabricated at least in part from low-conductive materials comprising fiberglass pultrusions.

28. A variable solar control window panel for a building energy system comprising a building enclosure having an interior and exterior, wherein said panel comprises a coating on glazing surface one or two, or on surfaces one and two of an exterior glazing substrate of multiple glazed window, wherein said coating or coatings comprises thin film multi-layer optical interference filters configured to selectively block solar radiation in depending upon an incidence angle of sunlight on said glazing surface.

29. The variable solar control window panel of claim 28 wherein said coating or coatings is installed on a suitably oriented south facing window in a building enclosure located between latitudes 30 degrees and 55 degrees in the northern hemisphere.

30. The variable solar control window panel of claim 28 wherein the seasonal reduction of direct solar radiation transmission substantially starts at an incidence angle of about 50 degrees and reaches a majority of required reduction at an incidence angle of about 60 degrees.

31. The variable solar control window panel of claim 28 wherein said panel comprises first and second glazing sub-
strates spaced apart and sealed around a perimeter edge, wherein said coating or coatings is located on a glazing substrate that is adjacent to the exterior of said building enclosure and wherein an ultra low-emissivity coating is located on a cavity face of the second glazing substrate adjacent to the interior of said building enclosure.

32. The variable solar control window panel of claim 28 wherein said glazing panel comprises three glazing substrates spaced apart and sealed around a perimeter edge, wherein said coating or coatings is located on a glazing substrate located adjacent to the exterior of the building enclosure and wherein an ultra low-emissivity coating is located on a cavity face of a glazing substrate that is located adjacent to the interior of said building enclosure.