Buildings for a Sustainable Climate

Sustainable, High Performance Air Conditioning Systems and Utility Plants
To Develop Sustainable, High Performance Buildings and Transport Systems

By Grahame E. Maisey, P.E. & Beverly Milestone
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Preamble

Two of the biggest global problems facing the world today are over-population and climate change. While these issues are inter-related, this paper sets out to solve a portion of climate change: the energy requirements of facilities and communities for buildings and transport. Providing clean air and water, and fertile soil for the future generations should be a prerequisite for every government, corporation, institution and individual. Discarding our responsibilities with excuses of economic and political necessity is simply avoiding a very big problem we have and are creating.

"The world we have created today as a result of our thinking thus far has problems that cannot be solved by thinking the way we thought when we created them."
Albert Einstein

We also believe that Einstein took for granted that all solutions would be based on a sound foundation of physics and economics. A sound economic foundation has not been the basis for the world economy for the last 50 years and the result has been the erection of a house of cards and its inevitable collapse. The global energy system that has been developed over the last 100 years is based on false economics and false physics to support the false economics. Even with the threat of sustainable design by many architects and planners, there is no plan in the 21st century for the next 30, 50 or 100 years for the millions of buildings and transportation for them that have been built to last into the 22nd century.

The current solution being proposed and initiated by the USA and Europe is that a sustainable global energy and economic system can be developed by slightly modifying the current false economics and physics. Baby steps will inevitably provide small improvements over a short time and negative improvements over the long term, one step forward and two steps back. This is not change. This has not, cannot and will not work long-term.

This paper outlines a science-based, step-by-step process that simultaneously safeguards financial stability and success while moving buildings, facilities and communities toward a sustainable, high performance future.

We should learn to base our future on a sound foundation of economics and physics, not modify systems that have been proven not to work. Karl-Henrik Robért developed a sustainable global platform with The Natural Step (TNS) concept in the late 1980's. There are many books on this topic that include projects for communities and different businesses. When TNS is coupled with sound physics and economics, we can develop truly sustainable solutions. Using TNS with unsound economics and physics has been the norm for building designers, slightly modifying their usual approach to falsely claim to encompass TNS. Keeping the integrity of TNS with the integrity of physics and economics will provide a comprehensive solution to most problems we have today with climate change with global warming and pollution of our air, water and soil.

Ensuring sound economics and physics with TNS and Einstein's theory of change, we developed Energy Master Plans (EMPs) for the built environment. Planning for a truly sustainable future involves a holistic and inclusive approach. EMPs include two other primary performance characteristics: maintenance, and building occupant health, comfort and productivity both in and around buildings, including transportation.

Climate Neutral Plans for facilities and communities should integrate Facility Master Plans and Transport Master Plans into the overall Energy Master Plan for a comprehensive carbon neutral facility, community, city or state. While these tasks may seem enormous and onerous, a steady development of our EMP with diligent application of well-established building and transport technology will provide the required solutions.

The greatest hurdle to overcome is getting politicians and people in positions of power to develop and commit to long-term plans. These people are committed to a short term of office and so naturally seek only short-term solutions that have a maximum foresight of 5 or at best 10 years. We need 20, 30 and 50year plans for 100year solutions for the global energy systems.

We need the hope that a very different attitude toward Mother Earth will help us heal or at least minimize our earlier indiscretions. The US and EU should be leading the charge as the most developed and technologically advanced nations, but party politics and greed by the politicians and industry leaders remains their leading goal. So it may be China that leads the way and becomes the leading world power by a sustainable revolution, revealing the weakness of democracy in the 21^{st} century.

Vision

When the temperature rises above 100ºF in the summer, air conditioning systems stretch electrical grids beyond their limits, causing brownouts and blackouts, while cars and trucks choke the air in towns and cities. Politicians and energy companies want to build "more robust" electrical grids, "safe nuclear" and "clean coal" power plants, costing trillions of dollars and creating more greenhouse gasses and pollution.

Let us envision a world 20 years in the future when most residential communities and commercial and industrial facilities are electricity generators rather than users, and most public and private transport runs on clean electricity. The electrical grid redistributes surplus electricity from sustainable buildings to energy intensive buildings and public transport during the day, and recharges electric cars and trucks at night.

This vision has buildings using little electricity and fossil fuel, and buildings or groups of buildings producing more electricity than they use during hot weather. Agriculture has converted to energy efficiency and the electric utilities use a only few efficient generating plants; transportation and agriculture use little gasoline. U.S. greenhouse gas emissions have been reduced by over 90%.

This vision may seem a fool's paradise, but such a vision is the kind we need today: Better to aim for a 100% reduction and fall short by a few percent than aim for 50% and achieve our goal. We believe we have until 2013 to put a plan in place and until 2017 to start to enact most of it to avoid catastrophic and perhaps irreversible climate change. So we are already late to start our evolution to sustainable development. This should instill a sense of urgency in people but it appears that most people either prefer to ignore the problem, deny the problem or are simply uncomfortable or are afraid of the enormity and consequences of the problem.

It is hope, not despair, which makes successful revolutions.

Can we create this sustainable energy future now, today? The truth is: Yes We Can!

We have the technology to achieve this vision today. We can build efficient electric vehicles and transportation systems. Sustainable buildings can be built except that current air conditioning (a/c) systems use far too much electricity, particularly at high outside temperatures. A 1988 Amory Lovins' report revealed that newer a/c systems performed poorer than older systems; they were less energy-efficient, cost more to install and maintain, and provided poorer comfort. This backward trend was caused by the oil crises of 1973 and 1979, a counter intuitive trend that continues today.

The solution lies in developing an Energy Master Plan (EMP) for every building and group of buildings both old and new. An EMP develops a comprehensive, detailed, step-by-step plan toward sustainable, high performance end goals: a zero carbon footprint, minimum, easy maintenance, and maximum occupant health, comfort and productivity, with extended life cycles. Sustainable buildings should produce more electricity than they use, repaying the energy used for construction and ongoing maintenance, as well as producing more electricity than they use at high outside temperatures. These concepts should be the primary requirements for defining sustainable building.

We are at the tipping point on many global issues including climate change, over-population, pollution, and the economy. Must we wait for a catastrophic meltdown similar to the financial system or should we use this economic recession to redirect our ideas to develop a truly sustainable economy and climate? The economic meltdown can be reversed and recovered from no matter how bad the situation gets but a climate meltdown is not recoverable.

Introduction

The solution to US energy problems will come from the consumer end. When consumers reduce their carbon footprint by over 80%, the US could reduce its carbon footprint by 80%. However, Politicians and Energy Companies want to build more electric generating plants and a more robust electricity grid, increasing greenhouse gas emissions, providing no long-term solution to the energy problems.

When consumers are no longer dependent on electricity or fossil fuel for their homes, offices, universities or hospitals and no longer need gasoline for their vehicles, their carbon footprint will have been reduced by over 80% by 2050, as required by some current international agreements. This should be the plan today, to work toward reducing the carbon footprint of all the people in the US by over 80%. While this appears to be a huge and impossible task, when we break it down into several tasks it will be found to be very doable with today's technology.

We can achieve the 80% reduction by integrating Facility Master Plans and Transport Master Plans into the overall Energy Master Plan for a carbon neutral facility, community, city, state or country. The basic solution is to develop buildings and their energy systems so they provide not only the energy for construction and operation, but also the energy for the transport of the people that that use them.

The primary advantage of sustainable buildings and companies is the long-term economic success and the economic advantages over less sustainable organizations. Truly sustainable buildings reduce the cost of construction throughout their life cycle by 70%, reduce the maintenance cost by 70% and are energy suppliers rather than consumers, saving all energy costs for the buildings and most of the transportation to and from the buildings. Where existing buildings or new buildings are incapable of becoming independently sustainable in their energy systems by themselves, a community or facility energy system will often provide the sustainable system. Sustainable buildings are bad for the current business model, using 70% less resources, and almost 70% less design and construction.

Sustainable buildings and communities provide the electricity that powers the transportation systems for the community. Gas/oil energy may need to be imported into the community when high intensity manufacturing plants are present in the community. This is the 10% we will have difficulty supplying.

The Limits of This Article

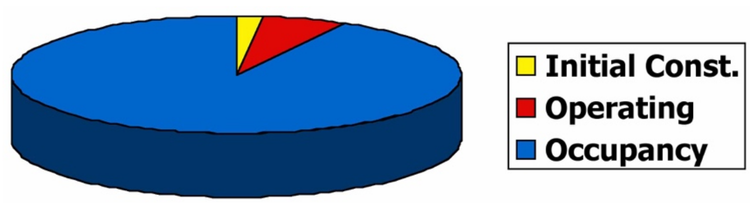
The aim of this article is limited to explaining how to provide an excellent thermal environment in buildings while also minimizing electrical and fossil fuel use and minimizing the maintenance requirements so the building can become energy sustainable as soon as possible in the future. Very little attention is given to lighting and electrical power systems, only sufficient to understand the interactions and care needed for the design of these systems. Far more care, consideration and expertise are required from designers and contractors to produce the results we need. As the buildings move toward carbon neutrality, so do the transport systems move toward carbon neutrality, integrated with the building and community energy systems.

Moving a building or facility toward sustainable, high performance requires step-by-step planning. Utilizing The Natural Step (TNS) tool of back-casting along with setting the end goal performance requirements is a good method for planning the systems to a sustainable future and avoiding pitfalls and blind alleys along the way. Developing an Energy Master Plan (EMP) for the facility that provides a detailed step-by-step plan for the building to become sustainable is a most viable and economic method of developing new or existing buildings toward a sustainable future. The EMP should be integrated with a Facility Master Plan (FMP) and Transport Master Plan (TMP) for an overall climate neutral plan for the facility or community.

The American Colleges and Universities Presidents' Climate Commitment (ACUPCC) is an initiative that has been signed by a 1,000 school Presidents in the USA. This initiative has similar goals to what is described in this paper. Unfortunately, there is little guidance on how to achieve their goals, only how to conserve 30% to 50% of the current building energy use.

Building sustainable homes, buildings, facilities, towns and cities will not only create healthy indoor environments, but will also fuel a sustainable US economic recovery and help curb greenhouse gas emissions so we can slow, and eventually halt and reverse, climate change and global warming.

Current Building and Mechanical System Designs

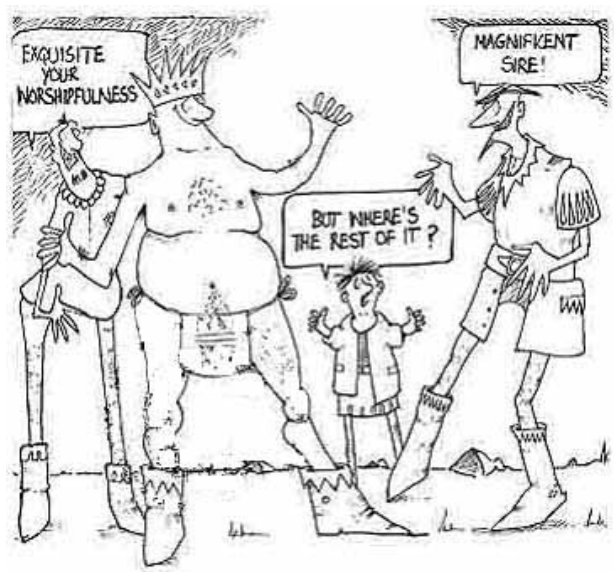


30 Year Total Building Costs

The pie chart above shows the approximate percentages of the current 30 year costs of a commercial building. The initial construction cost is 2%, the operating cost is 8% and the cost of occupants is 90%. Note that the annual income from the building comes from the occupants and is usually 115% to 150% of the operating costs. Therefore, providing optimum productivity conditions for the occupants should be the #1 priority of every commercial, institutional and industrial building.

Three mechanical systems are ubiquitous today with engineers, manufacturers, government agencies and professional institutions claiming the systems to be sustainable: Variable Refrigerant Flow (VRF), Ground Source Heat Pumps (GSHP) and Variable Air Volume (VAV) systems. All of these systems are really the worst choices for truly sustainable mechanical systems.

VRF systems often have ground heat exchange and a central refrigeration unit with many cassette units for every room or zone in the building. Building size can be from a small house to a 100,000ft^2 building. This all-electric system can control the humidity more successfully than other systems but it pumps refrigerant all around the building, a disaster waiting to happen. Ground source heat pumps are a ground heat exchange system, which is a really good thing, connected to water-to-air heat pumps, which are really, really bad things. Water-to-air heat pumps condemn a building to be an all-electric building with air systems, together with associated refrigeration units (heat pumps) spread throughout the building. All these systems require almost total remodeling to convert them to something maintainable, efficient and comfortable. The selling point for this system, which has been brilliantly sold by the Ground Source Heat Pump Consortium, is that it is 30% more efficient than a heat pump system *without* ground source heat exchange. And, of course, most government agencies and professional institutions have bought into this foolish claim and concept, allowing grants and reimbursements for installing these systems. Air source heat pumps are simply just 30% worse in energy consumption, but the extra cost of the ground source heat exchange often has a long payback.



Current Sustainable Design Methods, Analysis and Feedback of Results

Variable air volume (VAV) mechanical systems have been around for over 50 years and have yet to perform and provide the wondrous savings claimed for them. They have been re-invented every 7 years with claims that the newest generation of the system has solved the problems of the previous generation. How many system revisions must we tolerate for a system without obtaining the performance we were assured? VAV systems have conceptual problems that are never mentioned by engineers or manufacturers, and they cannot be solved: they rely on substantial maintenance being performed inside false ceilings where there is a huge number of moving parts; they rely on substantial commissioning being performed within false ceilings; they are all air systems that can never be very efficient or effective.

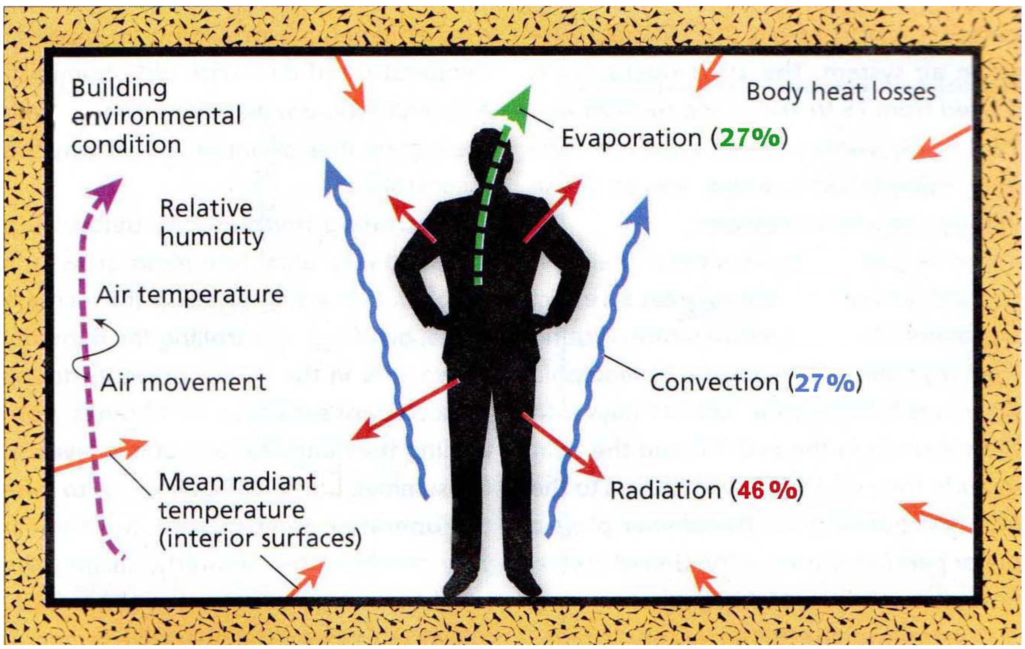
Our first step must be to release ourselves from the 100 year old concept of air conditioning: blowing air over a refrigerant coil or chilled water coil and a hot water coil in an air handler and distributing air throughout the building to ventilate, heat and humidify in the winter, and cool and dehumidify in the summer. Whether central systems or individual units, this system cannot provide good comfort conditions or minimize energy use and maintenance requirements.

It is time to examine different and alternative mechanical systems that can provide excellent life cycle performance in energy, maintenance and comfort conditions. We need to examine in detail every aspect of energy, maintenance and human health and comfort, utilizing fundamental concepts and principles of building physics and engineering in order to expect excellent results. We also need to examine the methods of design and construction to make them more efficient and effective so we can reduce the cost of new buildings and of remodeling old buildings.

Using Building Information Modeling (BIM) *WITH* expert planning, design, construction and commissioning can often reduce the cost of construction by an amount larger than the extra cost of most sustainable energy systems additions.

The Paradigm Shifts Required

The diagram below depicts the main factors affecting human thermal comfort. Note that the Mean Radiant Temperature (MRT) affects the radiant body heat loss by 46% while the air temperature and air movement affect the conductive and convective body heat loss by 27% and the humidity in the air affects the latent body heat loss by 27%. This implies that control of the MRT is more important for thermal comfort than controlling the air temperature. An extreme example is sunbathing during a ski trip: a still air temperature of 30ºF combined with a strong sun provides a comfortable thermal environment for sunbathing. Note also that evaporation is dependent on the humidity level in the room and is almost as significant for comfort as the air temperature.



Human Thermal Response to Room Thermal Environmental Conditions

Humidity control in all air systems is often the tail wagging the dog; the chilled water temperature is determined by the *humidity control* required *not* the amount of cooling required. We need to move to direct humidity control using desiccant systems because these systems not only control the humidity better but they can do it in an energy efficient way and use heat to achieve it. Humidity control not only assists comfort but also avoids health problems such as dry nasal membranes during a cold winter and mold growth in the summer.

The only real advances in mechanical systems in the last 50 years is the introduction of plastic piping that lasts for 100 years and digital controls that can accurately sense conditions and control a building mechanical system and apply daily and seasonal control strategies.

Applying comfort information will allow us to develop strategies for minimizing energy use while maximizing health and comfort. Strategies that could save energy include raising the MRT so we can lower the air temperature in the winter and lowering the MRT so we can raise the air temperature in the summer. Raising the humidity level in winter and lowering the humidity level in the summer are also strategies that could help save energy while maintaining a very high comfort level.

Defining Sustainable, High Performance

We need to establish end goals and objectives so we can begin developing strategies to achieve them. A sustainable, high performance building should be DEFINED BY:

- a zero carbon footprint:
  minimum electrical use at high outside temperatures; generating enough excess electricity annually to cover embedded energy in construction, maintenance and transportation energy.
- minimum, easy preventive maintenance.
- providing ideal occupant health and comfort conditions for optimum productivity.

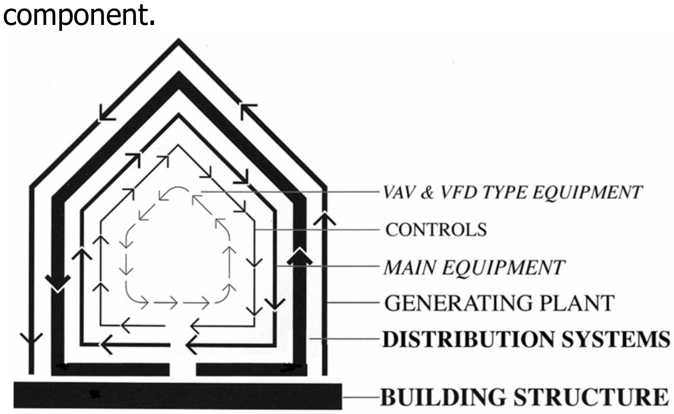
The goal of a zero carbon footprint or a climate neutral building is something that can be planned for and developed over time and need not be achieved immediately, but the maintenance and comfort goals need to be achieved from day one. The building should be constructed from non-toxic materials that have a long life cycle and require minimum construction energy. The design should be adaptable and expandable so that future modifications can be accomplished through minimum disruption, time and cost. A classic example of this is an office building where the initial design today would be for an open plan office but the adaptable design would provide a design so that it is easily converted to a cellular office layout or even be able to be converted to apartments or something similar. This is similar to the 1970's long life, loose fit mantra but adding the high performance element that was unfortunately the demise of the mantra.

The first energy reduction strategies should always be passive strategies: building shape and orientation, windows, insulation and mass of walls and roof; air tightness of the envelope is an essential passive energy controller. New and existing building conceptual design is an iterative exercise, integrating passive and active building systems, combining the passive with active systems such as people, lighting and air conditioning systems and observing different results from different strategies. Expert analysis must supplement computer performance analysis for systems life cycle performance.

Water Versus Air Systems for Building Mechanical Systems

We will omit all the theory of building thermodynamics and water flow in pipes and air flow in ducts, and examine classic examples of how to minimize electrical and fossil fuel use for building air conditioning systems, or as we prefer to identify them, building environmental control systems.

First we need to consider where and how energy is used in air conditioning systems by the various components. In the diagram below, line thickness indicates the relative percentage of longevity, energy use and the cost of installation. Note that the distribution systems, ducting and piping systems, use more energy, are the longest lasting and also cost more than any other component. These systems last between 20 and 100 years, use up to 50% of the annual energy used (all electric), and cost about 50% of the total installation costs. These systems are usually selected arbitrarily, yet they are far more important than any other component.

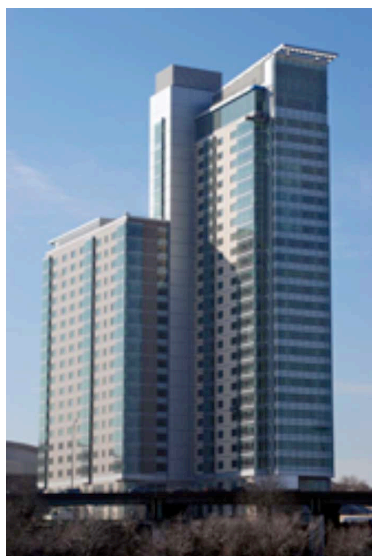


Relative cost, energy use and life cycle length of mechanical systems

The distribution system in large buildings determines the system type or style - an air versus a water distribution system. Let us consider the efficiency of pipes versus ducts as a distributor of thermal energy. Pipes use between 10% and 25% of the space ducts require and pumps use about 10% to 25% of the energy fans need to distribute the same amount of thermal energy over a given building area, and pipes cost between 10% and 40% of the cost of ductwork installation. These simple facts lead us to determine that sustainable air conditioning systems should use pipes to distribute thermal energy around buildings. Also, piping systems will cost less to operate and maintain and last for 80 to 100 years when well designed.

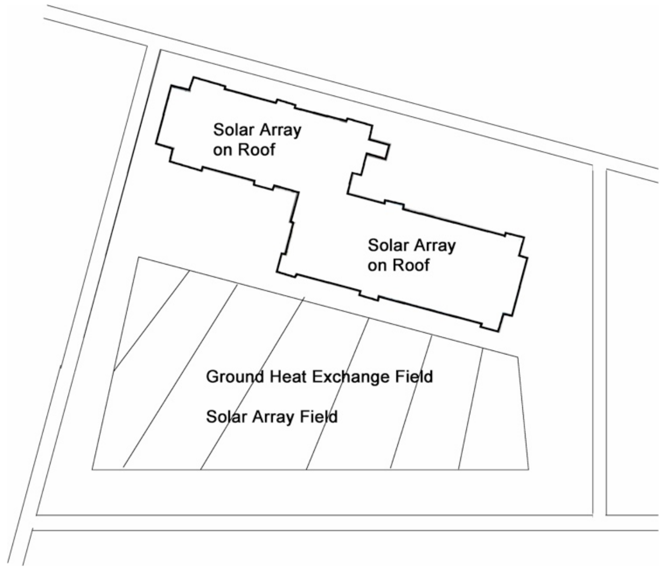
Pipe Size	Overall Pipe Size Including Insulation	Equivalent Duct Size	Overall Duct Size Including Insulation
1/2″	2″	8″ dia. (6″ x 8″)	10″ dia. (8″ x 10″)
1″	3″	12″ dia. (8″ x 14″)	14″ dia. (10″ x 16″)
2″	5″	40″ dia. (22″ x 60″)	44″ dia. (26″ x 64″)
3″	6″	60″ dia. (36″ x 80″)	66″ dia. (42″ x 86″)
4″	8″	80″ dia. (60″ x 84″)	86″ dia. (66″ x 90″)
6″	10″	100″ dia. (80″ x 100″)	106″ dia. (86″ x 106″)

Example High Rise Building Below is a Rendering of Theoretical High Rise University Dorm



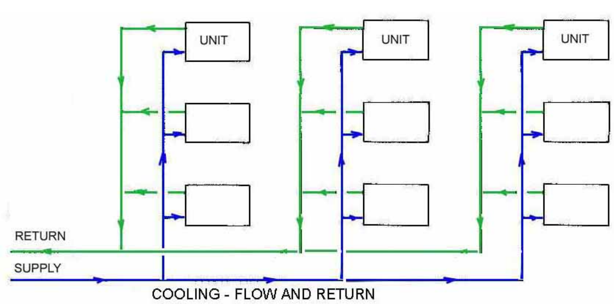
Consider a 28-story university dorm being built in Philadelphia. The total square footage is over 450,000ft^2. There is no energy master plan or energy plan for the building. The only plan is the initial plan of building a 28-story dorm for students to occupy now that is almost a carbon copy of a 24-story dorm built 2 years before.

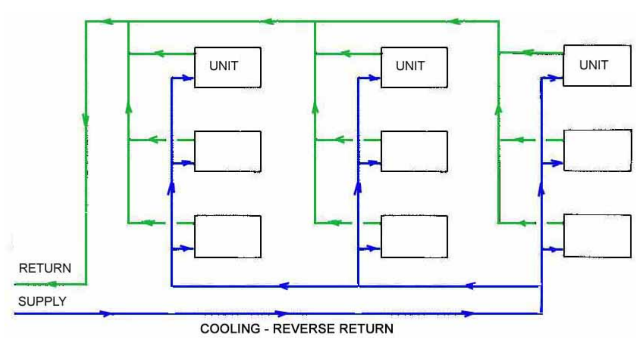
This, unfortunately, is typical; a total lack of life cycle planning and any demand from owners for long-term performance in almost every type and size of building. The owner of this building, a university, will pay for every aspect of the planning, design, construction, operation, remodeling and ultimately the deconstruction of the building. Yet they have no curiosity on the long term performance of the building. The owner has millions of square feet of real estate and no idea how to plan or take care of it. Their only method is to go back to the same designers who reliably messed up previous buildings. The mechanical system, including the distribution system, was selected to be the same as a recently built 24-story dorm: a 4 pipe fan coil unit for each dorm room and a variable air volume (VAV) system for the common space in each floor together with more VAV air systems on the first floor where there will be vending machines and a coffee area.



The orientation of the building was a North to South axis.
Sustainable Site and Orientation of Dorm, Rotated it 75°

Sustainable Configuration of Dorm

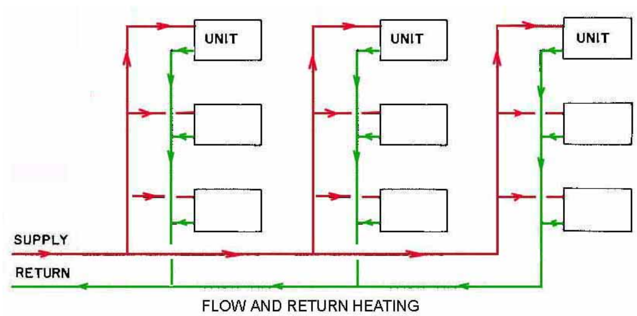


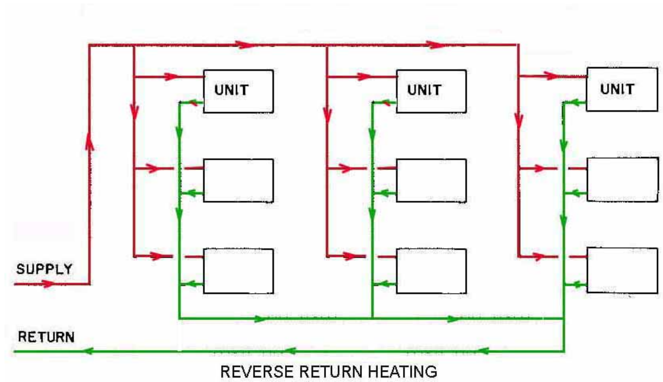


Chilled Water Piping Systems, Bad left and Good right

"Murphy" is alive and well, and lives in every building design, construction and operation. One of Murphy's laws is that the index piping run (furthest run from the pumps or fans) of any standard flow and return duct or pipe distribution system is where the first expansion will be required.

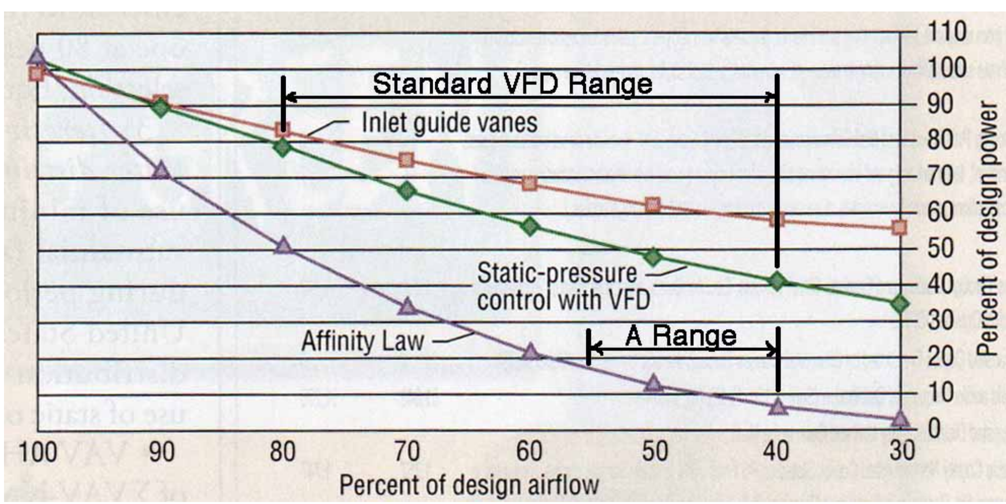
The above chilled water schematic piping diagrams serving the fan coils and variable volume air systems are shown for only three floors and three risers; there are 28 stories and 14 risers. The chilled water piping system shown above left is a typical flow and return system with a 30hp pump with a variable frequency drive (VFD) on the pump and the spare pump with VFD. The hot water piping system shown below left is also a typical flow and return system with a 25hp pump and typical VFD on the pump and the spare pump with VFD. Murphy says that the first place that will need expansion and more water is the top, right hand unit, the furthest point away from the pumps. Let us compare the flow and return systems to the reverse return systems shown on the right-side.





Hot Water Heating Systems, Bad left and Good right

First let's look at the diagram below which shows the relationship between percentage flow against percentage power required to achieve it for air systems. Water systems with pipes and pumps have the same relationship as air systems and fans. Note that adding VFDs to pumps changes a 10% power requirement for a 45% flow in the affinity law to a 45% power requirement for a 45% flow. Adding VFDs not only robs efficiency at low flow and assures that higher electric power will be drawn at high outside temperatures, it adds a huge specialist maintenance burden to look after the controls.



Electrical Power Vs Flow: Small Pumps & Large Pumps with VFDs

Changing the piping system to a reverse return system is recommended for several reasons. The reverse return system has no index or end run so every unit has an equal pressure drop to it, which in turn means each and every area is able to be expanded without much fuss. The piping system is sized based on maximum design temperatures and situations that in reality almost never occur, leaving the piping system oversized for normal peak operation. Increasing the flow from a 40% flow to a 50%

flow, a 25% increase, would increase the pump hp required from 1.75hp to 3hp. A 2.5hp pump is a good place to start with a slightly more oversized reverse return piping system.

The reverse return cooling water system has thermal circulation working for the pump instead of against it, saving power required to work against the natural thermal flow. When we examine the actual running loads on the building, we find that there is only a short time that anything over a 40% design flow is required, so we could use the affinity law line and install small pumps that would handle a 45% flow, theoretically 9% of the power needed for 100%, therefore our suggested 2.5hp pumps for both the hot and chilled water systems are sound recommendations.

In the flow and return systems, the power consumed by the pumps would peak during peak cooling and heating loads, exactly what we need to avoid in a sustainable, high performance building. If we added an extra 15% load, assuming the building will be converted to a ground source cooling and a low temperature heating in the future, not only will both piping systems be able to use a 2.5hp pump now, they will probably only need a 3hp pump in the future for peak loads.

Textbooks and technical articles on piping systems generally only point out the advantage of the reverse return system as self-balancing, requiring less balancing and commissioning. Textbooks and designers also assume that the calculated design loads will approximate the actual design loads when in fact, most calculated design loads are often 30% to 60% higher than ever required, particularly now that we have computerized controls which can preheat and precool the building during prolonged design conditions to minimize peak loads.

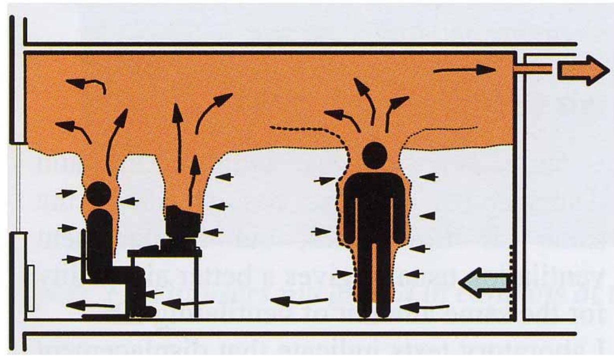
The original proposed flow and return systems were not adaptable, not expandable, not efficient and have a high electric demand at design conditions. They also had a very high maintenance cost for the large pumps and specialist maintenance requirement for the electronic speed controls and would need total replacement within 20 years when sustainable strategies are introduced into the building systems or expansion requirements exceed the piping system capacity. The fan coil units should also be optimized for minimal operating costs, and the five dozen variable volume air systems optimized similarly to the variable volume piping system, but it is a huge improvement to convert a building from being an inefficient, inflexible building with a predictably short life cycle to an infinitely better situation simply by examining the piping distribution system selection.

Moving a 450,000ft^2 28-Story Dorm Building Toward a Sustainable Future

All sustainable buildings require to be designed from day one to be sustainable. This requires planning the orientation and site layout to take full advantage of solar, wind and earth. This would change the dorm building orientation from North to South to East to West to take advantage of Solar on the large South wall. Also, it would minimize solar problems on the East and West sides. We would also seek to have a solar parking lot on the South Side and ground heat exchange wells on the South and North.

Preparing the main distribution system to be adaptable, expandable and efficient is the first and most important step. If the original flow and return systems are installed, a complete remodeling will be required, but with a slightly oversized reverse return piping system, conversion to a sustainable building becomes relatively easy.

A sustainable solution would be to replace the 1,000 fan coil units that service the dorm rooms with embedded radiant ceilings. This eliminates 1,000 fans, filters, and 2,000 control valves in the rooms and replaces them with 1,000 control valves in centralized equipment rooms, one valve for each room. The VAV air systems on each floor would be replaced by constant volume, 100% outside air units of approximately the same size.



Displacement ventilation is most effective with air volumes of 0.1 to 0.4cfm/ft^2

Displacement ventilation is 3 times more efficient at providing ventilation air to occupants than most ceiling air distribution systems. The amount of air required for ventilation is often only 0.1cfm/ft^2 with displacement ventilation, however, humidity control in most buildings east of the Mississippi will require more air, usually about 0.25cfm/ft^2 to 0.3cfm/ft^2.

The new air units would have desiccant humidity control and serve the dorm rooms outside air requirements as well as the central areas. The air systems would be displacement type systems, as the diagram above, to provide more efficient ventilation. The new air units would have all the controls within the plant rooms thus allowing for easy accessibility and preventive maintenance. The radiant ceilings and new air systems will eliminate the need for a peak cooling of about 1,000 tons of refrigeration by using ground source heat exchange directly, saving 1,000KW in electrical demand.

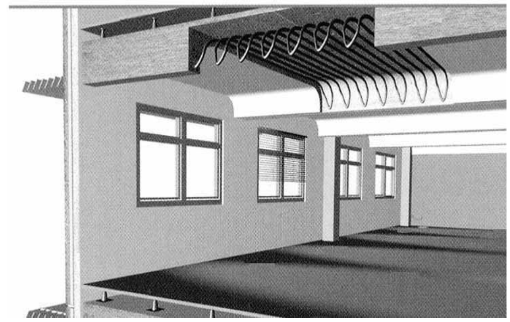
The new air systems will use about a 30% of the peak KW as the existing air systems, saving about 200KW demand. The reduction in electrical use of the 1,000 fan coils saves more electrical energy, about 200KW demand. The cost of installing a sustainable air conditioning system in the building from day one would add about $5 million, mostly coming from the radiant ceiling installation, with approximately $1M for the ground heat exchange installation. The initial maintenance saving would be about $250,000 per year and the initial energy saving per year would be about $1,000,000, giving a total saving of $1.25Million per year initially.

Comparing the old peak KW to the new, we have about 1,600KW down to 150KW, a reduction of over 90%. This approximates to 3.5Watt/ft^2 down to 0.3Watt/ft^2. It would be great to aim for 0.1 Watt/ft^2 for a peak mechanical system electrical use, but 0.3Watts/ft^2 can usually be doable with renewable electrical energy sources. A solar, and particularly a wind installation of 500KW, is very possible on the roof and surrounding parking, etc. Future solar PV developments will allow the building windows and fabric to become electricity generators.

To make the existing building wholly reliant on renewable energy is very difficult, a 1,200KW installation is difficult to imagine unless the whole southern facing façades were replaced with solar collectors as well as the roof. So if we have 0.3 Watts/ft^2 for air conditioning and allow a further 0.1 Watts/ft^2 for elevators and life safety systems, we have about 0.4Watts/ft^2 overall for a total of about 180KW load during peak outside temperatures. It should be relatively easy to generate 500KW during peak outside temperatures and so the building would be an exporter of electricity during peak temperatures, a step toward a sustainable future. It would be prudent to install a cogeneration system of about 300KW to provide both electricity and heat during the summer and winter so that the building could be a supplier of electricity during peak outside temperatures sooner than renewable energy systems would be economic, and standby power is advantageous in monetary savings.

The piping distribution system would allow the modifications to take place in a gradual and orderly fashion, probably two floors at a time for replacing the fan coils and air systems, then moving the chilled water system over to a ground heat exchange system after the whole building has been relieved of the necessity of chilled water. The original chiller load of approximately 1,500tons maximum load, leads us to suggest an 1,000 ton ground source initially. The hot water could come mostly from solar thermal and the ground source would supply pre-heating.



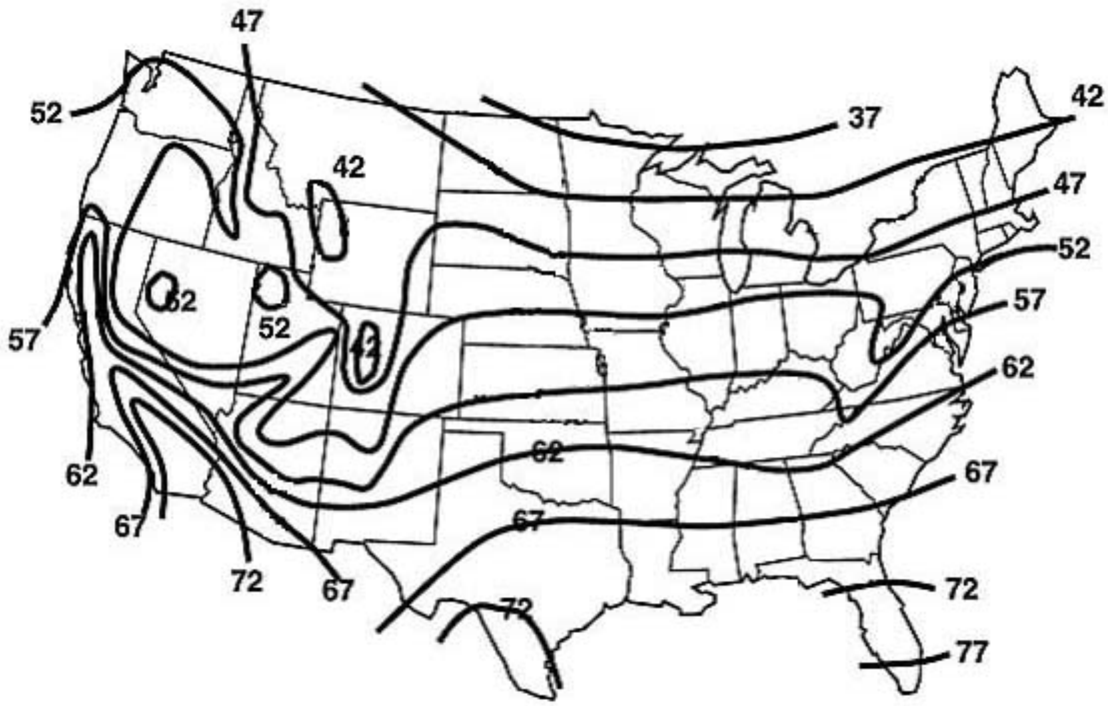


New or Remodeled Radiant Ceilings and Embedded Radiant

The diagram above on the left shows an embedded radiant ceiling installation for an office building that also has a raised floor for electrical distribution and potentially air distribution to displacement ventilation. The diagram on the right shows how we can manipulate the radiant temperature to increase the air temperature during the summer while still retaining a very comfortable environment. We do the opposite in the winter, increase the radiant temperature so we can reduce the air temperature and maintain very comfortable conditions. We can control the humidity level directly with desiccant air systems, lowering the level to 40% in the summer and raising it to 30% in the winter, adding to the comfort level while reducing energy use. 2018 NOTE: Our NEMCO LDAC system will help cool and warm the air and separately control the humidity while it filters, purifies and sterilizes 100% outside air. This reduces the transmittal of airborne infections and also reduces the CO_2 and other pollutant levels creating the optimum, healthiest and most productive indoor environment.

The extra initial cost of installing a sustainable mechanical system would have been about $5 million, or about 3% of the overall construction cost. In order to alter the building to a sustainable mechanical systems now, we would need to at least quadruple that figure. This is a good guide for estimating the cost of a sustainable mechanical building against a standard efficient building. **The extra cost for constructing a building that can *become* sustainable is usually zero.** Note that with better BIM and design and construction techniques, the building cost could have been reduced by more than 10%, much more than would be needed to be a sustainable building from day one.

The diagram below shows approximate ground source temperatures for the USA. NEMCO LDAC technology will use ground source exclusively for cooling and dehumidifying without further active cooling where there are ground source heat exchange temperatures available below 62ºF. In geographic areas where the temperatures are lower than 52ºF, there is generally a bigger heating load, and in areas where it is above 57ºF, there is generally a greater cooling load. Even where the ground temperature is below 82ºF we can make really good use of the cooler temperature when the outside temperature is above 90ºF and the wet bulb temperature is above 70ºF by using the ground source heat exchange and absorption refrigeration to cool the ground source water down to 62ºF.



Ground Temperature Isotherms for the USA

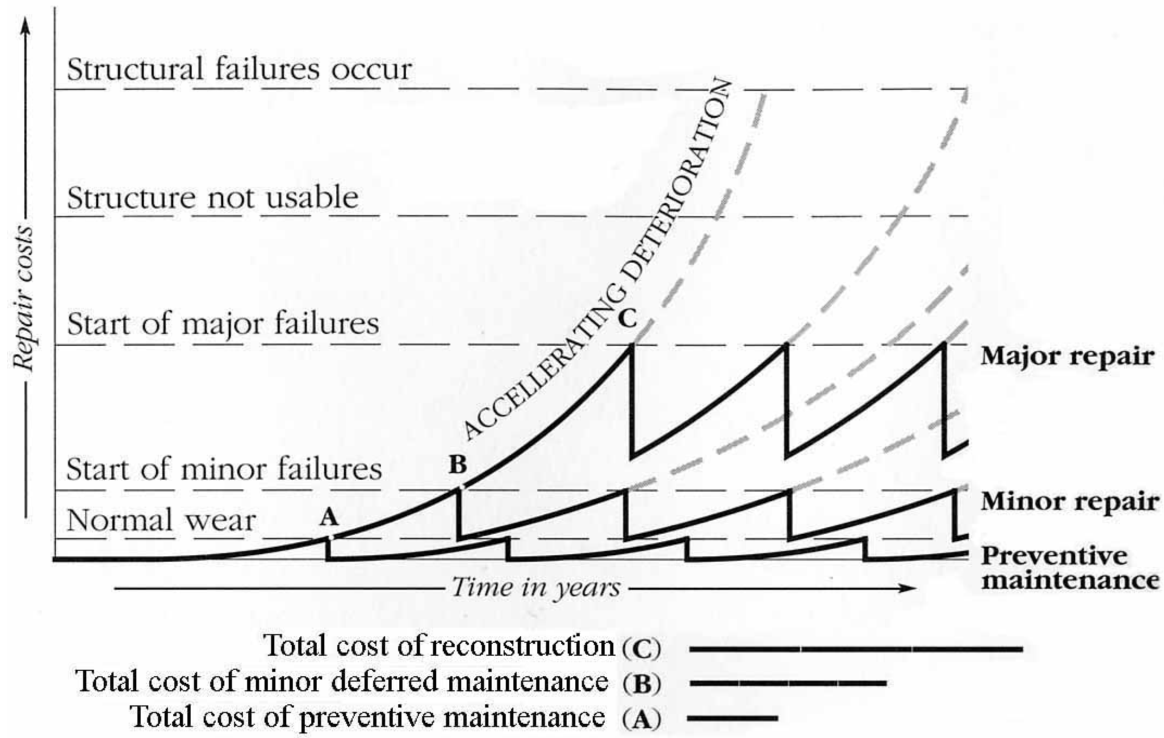
Where the ground temperatures are higher or lower than the ideal, annual strategies need to be developed, otherwise there should be an approximate heat balance between heat in and out of the ground during the year. Where there is more cooling required we could introduce pavement and parking lot snow melting or simply use them to cool down the earth during cold nights in the winter. Where there is more warming we could have solar thermal heating during the summer and fall months.

These developments would reduce the electrical use by over 90%, and the peak electrical load by over 90% while reducing the maintenance by 70% and greatly improving the comfort of the occupants. Electric refrigeration has been eliminated and a ground source heat exchanger provides all the cooling required in the summer and also provides pre-heating and snow melting in the winter.

Plumbing systems should be controlled to minimize or eliminate fossil fuel use, particularly during high and low outside temperatures. Planning water conservation, reuse and recycling in the building and surroundings is part of an EMP.

Lighting is another energy system that requires developing into a sustainable solution. In the case of this 28-story building, we need to develop a strategy for daylighting the building during high outside temperatures, which is usually between 10AM and 6PM during the summer when sunlight is present. Making use of a sun pipe system could provide a solution. The sun pipe system consists of a clear skylight with a reflecting tube transporting the light up to 40 feet vertically down into the building with a light diffuser in the ceiling. We need a horizontal version where skylights are on opposite sides of the building and the tubes run 20 to 50 feet into the building on every floor. This will allow a 120 foot deep building to be daylit and require only task lighting from LED or similar fixtures. No doubt this type of system will be developed further so that deeper daylit buildings will be possible.

Electrical power must be controlled during sensitive hours when the temperature is high, restricting power use by separating the power circuits of toasters, and electrical appliances such as washers and dryers, etc. Refrigerators, laptop computers and elevators are preferred uses during sensitive times.



Long Term Costs of Different Maintenance Strategies

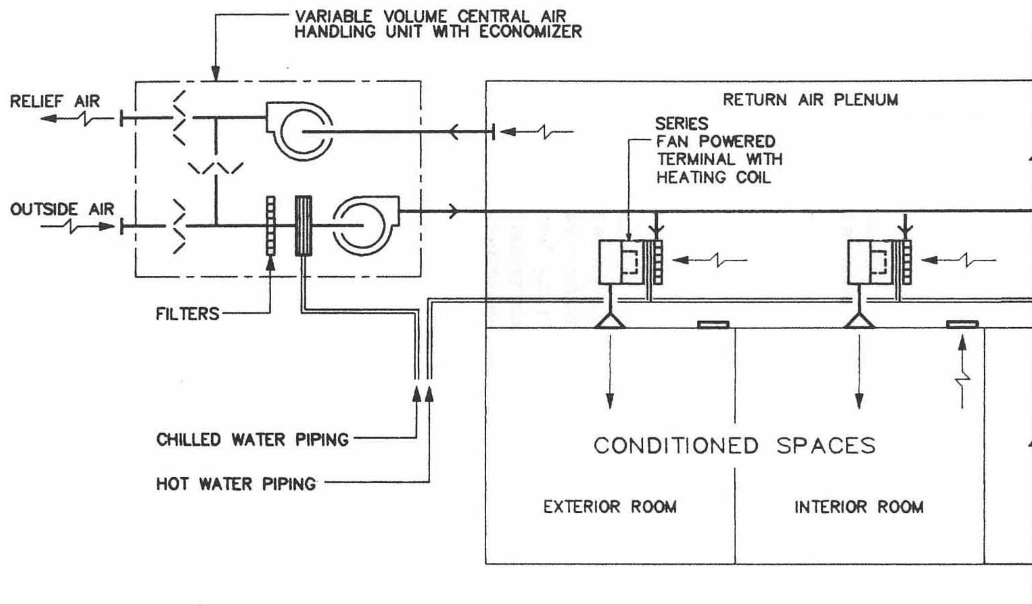
The diagram above shows the relationship of life cycle costs of different maintenance strategies. Preventive maintenance not only costs less but also assures that the systems are working at their most energy efficient while continuously providing the best comfort and productivity conditions.

About 70% of the commercial and institutional buildings in the USA currently have deferred maintenance, or worse, which represents billions of extra dollars in maintenance and energy, and even more billions in lost productivity. The full penalty for not having a preventive maintenance program is much more than increased maintenance costs: the energy efficiency is reduced and cannot be relied upon to produce the energy where and when needed; the comfort of the occupants is often the first penalty to be suffered, reducing the productivity and performance of the occupants, the prime reason for the building and its operation.

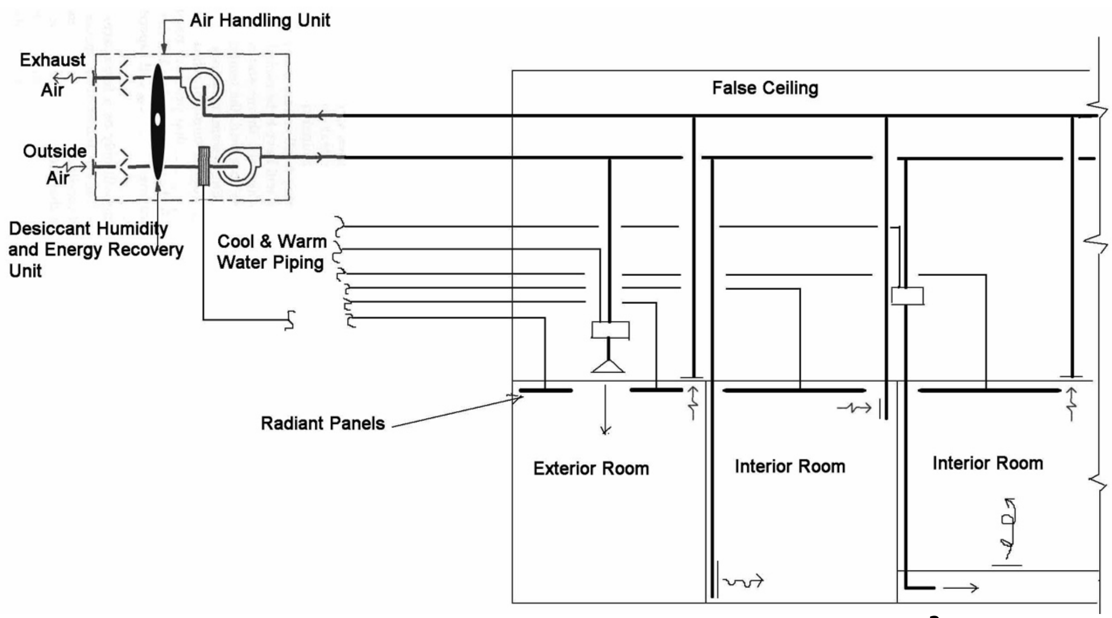
Developing a Sustainable Building Mechanical System From an Existing All-Air System

Most existing buildings have all-air systems for mechanical systems, served by chilled water for cooling and dehumidification and hot water or steam for heating. As noted above, the long-term solution is to move to radiant cooling and heating using radiant panels or preferably an embedded radiant ceiling system attached to the structure to make use of the mass of the building. 2018 NOTE: NEMCOLDAC air technology is the obvious choice for ventilation and humidity control, allowing 2x the required ventilation rates without an energy penalty to create a feeling of well-being.

This is where life cycle planning becomes an essential first step in developing or moving systems to a totally different system. Utilizing energy, maintenance and comfort performance improvements as part of the return on investment will often create a sufficiently quick payback to start the process in a building, if only to move one floor to experiment with the methods and assess the results.



A Fan-Assisted Variable Air Volume System, 1fcm/ft^2 Central Air, 1.4cfm/ft^2 Room

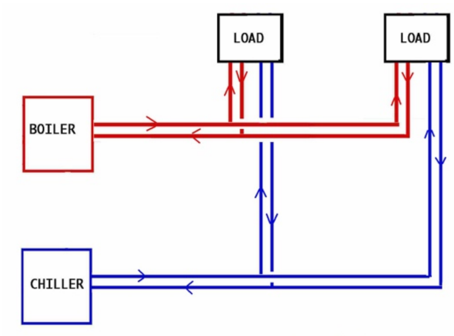


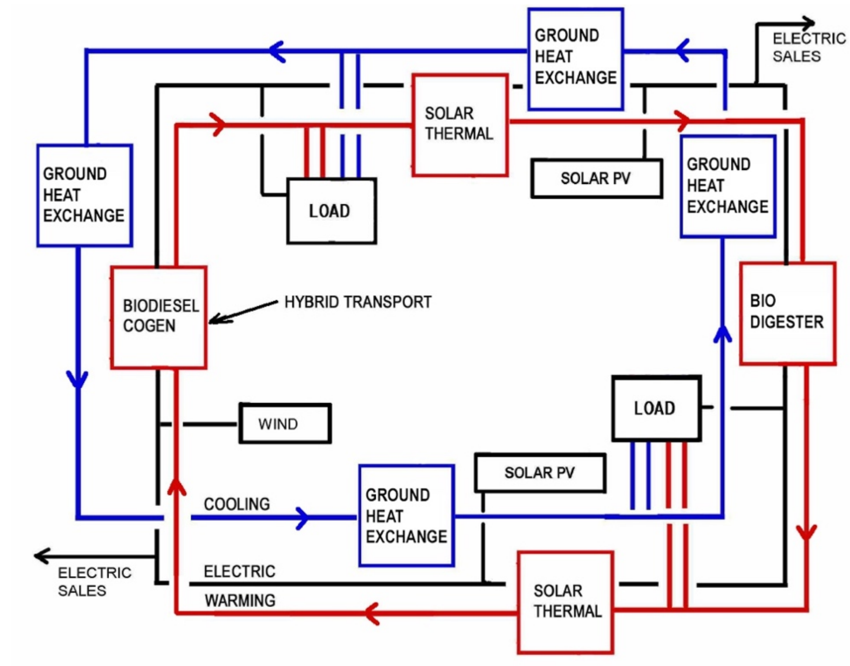
Radiant Ceiling + Air Options, Usually 0.15 to 0.5cfm/ft^2 Air

Minimizing the amount of air circulated and using 100% outside air are the other changes required to provide superior systems. There are better methods of introducing air into a room other than by ceiling diffusers. In a section above was an example of displacement ventilation, a very effective method of introducing a small amount of ventilating air into spaces. Note that the amount of air required is often determined by the humidity control required.

Developing Central Utilities for Universities, Hospitals and Communities, Etc.

Below left is a typical boiler plant and chiller plant with a flow and return piping system to buildings. The load is a building, a university, hospital or manufacturing plant. The boilers are often steam boilers that have an overall efficiency of about 50%. Chiller plants are often a combination of electrical and steam absorption refrigeration machines. Cogeneration and trigeneration plants are also being installed.





Current District Energy Boiler and Chiller System

Sustainable Energy Grid with Heating, Cooling and Electrical Systems from Clean, Renewable Sources

Above left is the current distribution style. Trigeneration systems are replacing the boiler and chiller plants. Above right is a sustainable energy grid. The cooling circuit is a ground heat exchange system, cooled by hot water absorption refrigeration where the ground temperatures produce water above 65ºF. The hot water circuit is usually between 100ºF for heating in the winter and 140ºF in the summer for dehumidification and cooling. Note that the pipe circuit could be a single pipe system that not only saves money in installation but could also be extremely efficient in operation. The electrical circuit is served by many different sources. Moving over to a sustainable central utility first requires the individual buildings to move to systems that can utilize these sources.

The surplus electricity can be used for charging cars and trucks during the night and running trolleys and trains during the day while also supplying other communities and energy intensive industrial parks, etc. Communities can share services to form larger energy systems that can include water, sewage, waste, etc.

Putting Everything Together

Developing sustainable, high performance buildings, facilities, communities, cities and states should be the goal and objective for the USA and all the developed countries. Using renewable energy sources, including ground, solar and wind for most buildings and districts should be part of every plan.

Energy Master Plans (EMPs) should be required for every new building and every building undergoing a major retrofit. The plan should take a building, facility or community from their current situation to a sustainable, high performance future. EMPs optimize the energy systems of a building, facility or community. Facility Master Plans (FMPs) provide long-term plans for the building and environs and should be integrated with the EMP for a sustainable plan. A Transport Master Plan (TMP) should also be integrated into every school district, college and community plan to form a comprehensive energy systems plan.

In the case of the 28-story building, if the owner was more vigilant and prudent and wanted to optimize the design and construction process and reduce the cost, a good BIM system with designers and contractors working with it would have reduced the overall cost significantly. The radiant ceilings could have been installed along with the desiccant, 100% outside air systems for an extra cost of less than $5 Million. The ground source could have been installed for less than an extra $1 Million. Also in the planning would have been a provision for horizontal light tubes on the sides of the building, or these could have been installed for an extra cost of about $10 Million, less than the savings from utilizing BIM. An EMP would have also included provision for a wind and solar PV installation on the roof and solar PV in the parking areas; together with a south façade that could become solar PV.

Thus we see that by optimizing the design and construction process and using the best BIM systems, we can save more money than is needed to pay for the extra cost of constructing a building that is well on its way to becoming a truly sustainable building. **When we eliminate the inefficiencies in the design and construction process, we have more money available than is needed to develop truly sustainable buildings.**

Utilizing EMPs when pre-planning and developing the project with a TQC/TCA program such as our Total Quality Commissioning process will help provide the optimum design strategies. Utilizing the best BIM and computer performance modeling, together with expert analysis and evaluation and comprehensive documentation will provide huge savings for the project in construction as well as optimize the design solution and process. Selecting experts for the design and construction process is the first important step for the building owner.

Most owners use designers they have used in the past as they have developed a relationship and a comfort with the way they work and the people involved. However, the necessary big change requires a shake up in the way things are done, so new people and methods need to be included on projects, even if the same design team is utilized. Most designers are willing to move to different design approaches in order to develop their skills toward a sustainable design direction, so the new people in effect train the designers in new methods. Too often the new people apply new cookbook approaches, using LEED as the sustainability platform when it is really a small step toward sustainability and should be considered as such. If there is to be a cookbook approach, it should be based on TNS with an EMP so we have the clear goals and objectives of a sustainable, high performance solution, together with strategies to achieve them.

Note that in order to be successful, we need to optimize systems for comfort and productivity as the first and most essential priority and performance characteristic. We also need to assure that the systems are easy to maintain. This can be accomplished by following the laws of sustainable maintenance. These laws are that every moving part must be in a plantroom or utility closet, and that all moving parts and equipment must have easy access for inspection, cleaning, lubrication, maintenance and replacement. Moving toward a zero carbon footprint will only be possible and successful when the above two conditions are also achieved.

Assuring quality control from day one requires a Total Quality Control system. A Total Quality Commissioning program could provide the TQC/TCA plan solution. The TQC/TQA program should start at the very beginning of a project to assure all the systems selection and sizing are optimized and integrated for the project. Systems selection and sizing together with integration produces over 90% of the results. Poor system selection, sizing and integration followed by the best commissioning in the world will still produce poor results. Current commissioning and even advanced commissioning does not fulfill these requirements. We require that the commissioning engineer or consultant has a detailed knowledge of how the systems work throughout their whole life cycle so that they can suggest better ways of system selection and better sizing strategies and integration methods to optimize the system design.

The oldest and best known quality control system in construction is Measure Twice, Cut Once.

$MEASURE_2$ is what we provide to be able to CUT_1 and provide a life cycle performance solution for the project from day one.

A checklist of what performance characteristics we require:

M – Maintainable	Easily maintained over a long life cycle
E – Effective	Healthy, comfortable and productive indoor environment
A – Adaptable	Adaptable to different situations and requirements
S – Sizing	Sized for prudent whole life cycle performance
U – Utilities	Developed for a sustainable whole life cycle future
R – Remodeling	Able to be remodeled with the minimum of time, effort and money
E – Expandable	Able to be expanded or contracted with minimal time, effort and money
E – Efficient	Able to move toward a positive carbon footprint where possible

To provide a sustainable, high performance life cycle solution:

C – Comfort	Provide the best occupant comfort from day one
U – Utility	Adaptable, maintainable, expandable for a whole, long life cycle
T – Thrift	Least cost solution from day one through the whole, long life cycle

The Way Forward

The world now stands at the crossroads: Global economic meltdown and global warming are two problems that must be confronted and resolved. One way to deal with both of these issues is to ensure that all buildings or groups of buildings, new and old, are net zero energy, high performing, sustainable buildings. The first step to achieve this goal is the most difficult – a life cycle plan for every new building and major remodeling project on existing buildings. In order to attain these goals, every building project must include an Energy Master Plan. The EMP will show the way forward, step by step, to achieve the end goals.

In the case of existing buildings, facilities and communities, the EMP will begin with the current situation and then delineate the steps necessary to make the building(s) sustainable and high performing. The plan will show how some steps one would think of as being sustainable, in fact, lead only to a dead end and so must be rethought. A classic example of a dead end solution is happening today, endorsed by almost every government agency and institution: ground source heat pumps with individual water to air heat pumps distributed throughout the building. This system is creating all-electric buildings that will require almost total remodeling to remove the systems. For new buildings, the plan will provide the necessary guidance from day one, to attain true sustainability in the future.

The time is now for engineers, architects, and building owners, and in particular political leaders, to commit to net zero, sustainable, high performing buildings and integrate the built environment with transportation systems. Local and state governments and the federal government are offering many incentives to help along this path. We need to show the world that the United States is the leader in sustainable building practices.

NOTE: A 2018 update is the NEMCO LDAC patented technology. This is the answer for the Heating, Ventilating and Air Conditioning air handling unit requirements, fulfilling all the performance requirements for high performance, positive energy buildings.