Zero Energy Consortium

Mechanical Systems, Plumbing and Controls WG Draft Report

This section of the report addresses mechanical systems and equipment that incorporate the Heating, Ventilation, and Air Conditioning (HVAC), the use of water and fluids, and the controls for operation and optimization of a building that will contribute to the goal of Zero Energy in buildings.

As is discussed throughout this document, achieving zero energy requires maximizing the efficiency of all building systems, including the envelope, lighting, major equipment like elevators, miscellaneous equipment like computers, copiers, refrigeration systems, cooking, laundry, small appliances, etc. and the mechanical space conditioning systems. When this is done then it is possible to supply the drastically reduced energy needed to operate the building with renewable energy sources like photovoltaic's and wind. Figure 1 illustrates this approach. Needless to say, all of these systems must meet reasonable cost-effectiveness criteria, but the limited footprint on most commercial building sites for photovoltaic's and the trade-off in cost between these renewable energy sources and energy-efficient building systems favors emphasis on the efficient systems side of the equation.

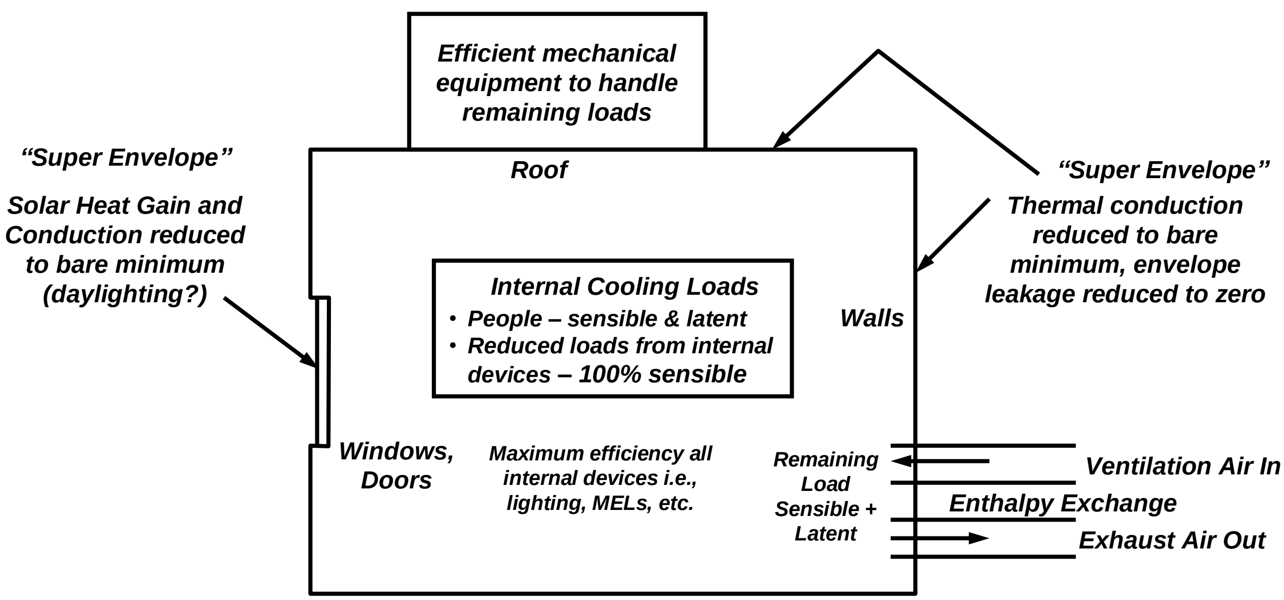
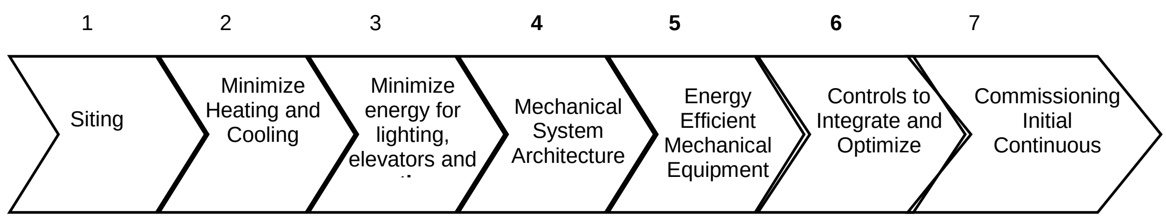


Figure 1: Zero Energy Commercial Building – Energy Reduction Side of the Equation "Super envelope", Efficient Ventilation, Maximum Efficiency Internal Devices, Efficient Mechanical Systems -- All are Needed to Minimize Energy Input

To begin the process it is necessary to review the methodology in delivering a building and where the mechanical systems portion fits. Below is a diagram that outlines this thought process and it can be seen that the areas of concern to this WG starts at step 4 and comprises steps 4 thru 6.



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- Step 1: Pick site. Recommend siting buildings to take advantage of weather and available energy sources where possible. Examples include:
  - Siting data centers in cool dry climates to encourage the use of free cooling
  - Group buildings in communities where energy can be recycled and recovered.
  - Buildings next to water sources for free cooling
  - Building near sites where geothermal, wind and other renewable sources can be used
  - Orienting buildings to minimize energy gain and loss

- Step 2: Minimize heating and cooling loads – This involves a high performance envelope with minimum indoor to outdoor thermal conduction and cooling season solar heat gain (consistent with day lighting) along with step 3. Also make maximum use of free cooling, natural ventilation and other low energy intensity heating and cooling methods.

- Step 3: Minimize energy for lighting and internal plug loads, both to minimize the direct energy consumption and to minimize the contribution to cooling loads. This should include time of day scheduling and occupancy controls and temperature reset where applicable to only run systems when needed at the maximum possible efficiency.

There are additional considerations when Step 2 & 3 are optimized that affect the technologies and systems that will be used:

- Ventilation related load becomes a larger fraction of total cooling or heating load
- Internal loads
  - Larger fraction of cooling load
  - Contributes proportionally more to space heating capacity in cold weather

- Wider variation of the sensible heat ratio of the cooling load and an overall increase in latent loads as percentage of the total load
- Lower outdoor temperatures coincide with a net cooling load – more potential for economizers and other free cooling and heat recovery systems
- Wide range of cooling load/temperature lift combinations
    - Cooling load variation is as much occupancy driven as ambient conditions driven

- Step 4: Mechanical systems architecture

It is our contention that to approach zero energy the approach to mechanical systems architecture must be changed. That is, it is necessary to consider reusing, storing energy before the consideration of what additional energy will be necessary to operate the building for occupant health and productivity. It is also recommended to minimize the use of any natural resources that are considered to be available in the site area unless these resources can be restored for use continuously. Therefore, this WG considers technologies that will address these areas as necessary in Step 4 before the consideration of energy efficiency in equipment and systems. Climate and environmental considerations are also necessary to develop the mechanical system design.

- Reuse/recover energy
- Utilize low energy intensity sources (geothermal, evaporative cooling in dry climates, desiccant cooling)
- Minimize the use of natural resources: water, fossil fuels etc.
- Store energy for later use
- Active controls of time of day scheduling, setpoint reset, occupancy ventilation control.

Since each piece of equipment, added components and connections form a system it is the opinion of the WG that new and meaningful metrics will be required to properly characterize the performance of these systems. Additionally, many of the technologies presented are more effective and intended for use at loads less than design since buildings operate at less then design more than 99% of the time. Some of the system components have part load metrics, many do not and should have them to enable proper characterization of the performance in the building. Also there are very few metrics that allow for evaluation of hybrid systems where two concepts are combined and used as needed during the annual operation.

It should be noted that to really optimize the operation of the mechanical system over the building load profile requires advanced tools that are accurate and easy to run. In addition to the new metrics discussed above. Certainly, there are tools today but they are expensive to run and only good for comparing options, however considerable work is required to improve these tools to be really effective for evaluating design options for all buildings.

The current delivery system for building design is a fragmented non-integrated system which does not encourage the use of integrated optimized designs. It is our contention that the building delivery system must change. It will be no longer be acceptable to plan, design and execute a building using the current “silo” approach. There is also one additional fundamental truth:

There is no one answer to get to zero energy. There is no “silver bullet” technology to address all buildings in all weather zones and it is clear that the conventional approaches to improving building and mechanical system efficiencies will not in themselves result in net zero energy buildings

To begin to understand the complexity of system architecture and design it is necessary to identify and categorize the systems, equipment, and technology options that are available today and will be available in the future that are cost effective and realistically possible in the foreseeable future. The chart below attempts to place these options into an understandable and meaningful matrix. This chart is expanded as an attachment to include a weather dependent determination as well. (Attach Technology matrix spreadsheet)

Technology Matrix

	Primary Function of Technology	Common and Promoted Commercially Available Technologies	Underutilized Commercial Technologies	Emerging/Developing technologies
		1	2	3
A	Recover/Reuse		Commercial Energy Recovery Ventilation Systems Integrated Energy Recovery Ventilation Systems Air Handler Integrated Energy Recovery Ventilation Systems Unitary Commercial Ground-Source Heat Pumps Distributed Energy Recovery of Process Waste Heat Heat Pipe Off peak cooling and Heating coupled to thermal storage	Commercial Ground-Source Heat Pumps Centralized Earth Tube Ventilation distribution system Solar Power Concentrators - passive.
B	Minimize Natural Resources		Water/air/refrigerant Economizer (Free Cooling) solar water heaters Solar thermal space heating	
C	Energy Storage		Cool Storage Integrated Lighting / HVAC Controls.	Advanced Thermal Storage Materials/Systems-Building Thermal Mass
D	Efficiency	Advanced Rooftop Packaged Air Conditioners Demand-Control Ventilation Evaporative Cooling Direct Evaporative Heat Rejection Applied Modulating Boiler Base Board hot water heating	Advanced Fan/Blower Technologies Commercial Ductwork Optimization Electronically Commutated/ Permanent Magnet/Brushless DC Motors Hybrid systems Improved Duct Sealing Radiant Heating/Cooling Variable capacity equipment for Heating and cooling as well as staged multiple units Variable-Speed Drive Building Automation System Air to water heat pump chillers Commercial condensing boilers Dedicated Outdoor Air Systems Point of Use Water Heating Water to water heat pump chillers Active Chilled Beam Cooling with DOAS Variable water Flow Systems Alternative Air Treatment (to reduce OA) Desiccant Dehumidification Systems Microchannel Heat Exchanger Underfloor air distribution Variable Refrigerant Volume/Flow Mechanical Insulation Systems (HVAC, Piping , Equipment, Boilers etc) Electric motors with integrated variable speed drives Centrifugal pumps with ECM motors Centrifugal pumps with integral motors and variable speed drives Zone instant hot water heaters	Commercial heat pump water heaters Commercial Hot-Dry Air Conditioners Customization of Unitary HVAC Equipment Dehumidification Enhancements for Air Conditioners in Hot-Humid Climates Evaporative Cooling Indirect Improved air side zoning systems Right Size HVAC Equipment Advanced Compressor Variable/High Speed Advanced Northern Heat Pumps Advanced vapor compression cycles Displacement Ventilation Evaporative Heat Rejection Unitary High Efficiency "Gas-Pack" Rooftop Packaged Air-Conditioner Liquid Desiccant Air Conditioner Modulating Furnace Next Generation Refrigerants Pond Based Ground Source Heat Pumps - Cooling
E	Controls		Automated Fault Detection and Diagnostics for Rooftop Units Complete/Retro Commissioning	Adaptive/Fuzzy Logic Controls System/Component Diagnostics System/Component Performance Diagnostics Zonal Ventilation/Control Personal Thermostat (e.g. Ring Thermostat) Microenvironments / Occupancy-Based Control Centrifugal pumps with ECM motors and intelligent controls Open loop day time HW Solar Heating / Night - Instant HW heating.

One obvious observation from the matrix is that there are a significant number of underutilized commercially available technologies (group 2) that can contribute to the Zero Energy goal sooner rather than later. This revelation suggests that more support effort and attention should be paid to determining which set of system components would be a "best practice" in a given environmental zone while also looking at technologies that are emerging or developing for use in the distant future. This could include support from government agencies and utilities to speed the introduction of emerging technologies.

- Step 5: Select efficient equipment/systems.
  1. It is important to select equipment that is efficient not only at the design conditions but over the full operating range for the building.
  2. It is also important to properly size the equipment which requires improved and accurate load estimating tools

- Step 6: Fully integrated control system

  1. A greater degree of control sophistication and "smarts" will be needed to optimally combine free, recycled and stored energy while operating powered equipment needed for remaining loads at maximum efficiency.
  2. Controls will also play an important part in the commissioning of the building , listed in step 7
  3. advanced software for prognostics and diagnostics of the building operation.
  4. The overall contol system should have a visual display with the key metrics in full view. These metrics should be relevant to those monitoring the system Ie. Energy use, financial ROI, data points, maintenance and diagnostic tools.

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- Step 7: Initial/continuous commissioning

  Studies have shown that buildings often do not operate as intended. Much of this comes back to the initial commissioning and on-going maintenance (continuous commissioning). Advances in controls and software as well as sub-metering is a very effective way to improve in this area. To achieve Net Zero buildings will require significant changes to initial and continuous commissioning.

  All of the above is an integrated process with the appropriate DDC integrated and intelligent controls at all levels. Visual feedback reporting relevant to the individual asking for the information.

  Status discussion: The above listing of efficient mechanical system options for heating and cooling is reasonably comprehensive. Technologies have been classified with respect to energy saving function and with respect to commercial status. It is striking that while there is a solid core of efficient heating and cooling technologies that are in full scale production and use now that can be used to implement a zero energy commercial building, there is also a large number of commercially available technologies that can provide additional, cost-effective energy savings now that are seriously underutilized. A significant number of technologies are still in either the emerging or developmental stage that could contribute further to energy savings in appropriate applications.

- Group 2 factors

The underutilized technologies are available now for use in appropriate zero energy designs, however if they were more widely utilized, they would probably be lower in cost and therefore more cost-effective to use. The following is a brief list of market barriers and actions that might be undertaken to overcome these barriers and encourage wider use.

- Market barriers
  - Short term payback mentality
  - No DOE encouragement
  - Lack of recognition in standards/codes
  - Metrics for systems/part load
  - Lack of Exposure, lack of education
  - Never a core technology until large HVAC companies with large channel distribution adopts
  - Contractor base dedicated to core, mainstream technologies due to cost, complexity, lack of knowledge,
  - Plan/spec contractors not prone to embracing integration and energy optimization
  - Modeling programs do not include all of these technologies
- Overcoming barriers
  - Rebates
  - Incentives
  - Updating standards and codes to recognize underutilized technologies but define the end requirement and not the technical solutions
  - Education by DOE and others
  - Simple modeling programs with technology plug-ins that are accurate and low cost to operate
  - Demonstration programs for technologies
  - Building delivery system transformation
  - Development and support of system metrics used to characterize the actual efficiency/performance. Recognition of these metrics by utilities and other entities for incentive verification.
  - Develop ways to further utilize renewable energy sources on or off site

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- Group 3 factors
  - Market barriers

    The group 2 factors and:
    - Capital investment community
    - Company/DOE resources
    - Short term ROI focus vs LCC return/considerations
    - Minimal understanding of how systems and operation contribute to the asset value of the building/complex

The technologies that are classified as emerging/developmental fall into two main function categories – energy efficient systems and controls. The control technologies which all are different versions of advanced, intelligent controls is important, because the effective coordination of stored, reused, and free heating and cooling sources with efficient mechanical systems will require a higher level of controls integration. The ability in real time to optimize the operation of multiple systems, to anticipate and exploit changes in conditions, and react to changes in occupancy offer the potential for significant energy savings while delivering a high level of occupant thermal comfort. In addition, intelligent controls can recognize a variety of energy-wasting fault conditions and either correct them directly or notify the building operator that corrective action is necessary. This is often referred to as diagnostics and prognostics

To achieve optimum control, a higher level of sensor and measurement accuracy may be necessary. Control systems should be user-friendly and provide meaningful reports to facilities management, enabling needed corrective actions, to either mechanical system hardware or to control algorithms, to be identified and implemented. One area of deficiency at this time is the measurement accuracy and reliability of sensors used to determine the latent component of the load. This is one area of the system that has tremendous opportunity for improvement and is necessary to achieve sustainable net zero.

<u>Summary</u>

The input provided by the MSPC WG was insufficient to adequately cover plumbing and controls in a more comprehensive manner. In addition, the WG feels that mechanical systems design, technologies and application a result of a proper approach to building design that is not prevalent in the industry today. Unless a new approach to building delivery becomes the norm, Zero Energy is cannot be obtained in the foreseeable future. The entire industry must transform to embrace a methodology that tends to more integration of thought, design, systems and controls that ever before. As we have pointed out, the technologies are available when properly applied to allow nearing zero energy, but the integration model does not.