MECHANICAL SYSTEM COST EFFECTIVENESS STUDY

FOR

SLAC KAVLI BUILDING

Prepared for:
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Executive Summary

A mechanical systems cost-effectiveness report has been prepared following preliminary discussions with the Kavli team regarding the choice of mechanical system that was originally presented in the feasibility stage of the project. This report has been prepared to show the costs and benefits associated with two system choices.

Two mechanical systems were evaluated for use in this project: an overhead VAV system and an underfloor air system. Both are good quality systems that could meet many of the project criteria. The key difference is the flexibility afforded by the selection of the underfloor system.

An energy simulation performed to compare the energy use of each system shows that there is a potential savings of almost 1.75 kWh per square foot per year with the underfloor system compared with the overhead system. As shown in Table 1, a comparative dollar savings estimate of $4,570 has been made between the two systems.

Table 1: Annual Energy Consumption

Alternative	KWh/ft^2 per year	Potential $ per year
Underfloor	8.11	$29,155
Overhead VAV	9.83	$33,725

On the capital cost side, there is a $1.36 per square foot premium currently shown for the underfloor system. However, this does not include any savings that could be realized through a reduced building height due to less plenum space required for HVAC equipment combined with the cost savings of installing a full ceiling. It is noted that some costs will be incurred for ceiling treatment in the building, especially in the theater but it is still shown as a reduced cost over the Overhead VAV system, which requires a full ceiling installation. The capital cost summary can be seen in Table 2 below.

Table 2: Capital Costs per Square Foot

Cost Component	Delivery System	
	Underfloor Air	Overhead VAV
Structure		
Floor Sealing & Curbs	$1.00	$0.50
Architecture		
Raised Access Floor	7.00	0.00
Shaft Construction	0.23	0.23
Floor to Floor Height	0.00	0.00
Ceilings	5.40	6.80
Fireproofing	0.00	0.00
Mechanical Systems		
Wetside Equipment	4.29	5.20
Dryside Equipment		
AHU’s	4.10	4.40
VAV’s	0.96	1.80
DX Units	1.00	1.00
Diffusers	2.04	1.07
Dampers	1.28	1.44
Thermostats	0.18	0.23
Ductwork	4.50	7.00
Pipework	2.40	2.40
Controls	1.65	2.00
Electrical Systems		
Equipment Power	0.56	0.66
User Power/Tel. Distribution	2.50	3.00
Lighting	$0.00	$0.00
Total Cost	**$39.08**	**$37.72**

Taking into account several different considerations for determining the mechanical system to be used in this project and based on a building consensus approach, it is recommended that the user group and project team determine which criteria – capital cost, operating cost or flexibility – are the determining factors in this decision.

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Scope of Study

A study was performed for the SLAC Kavli Building to evaluate the cost effectiveness of the use of the two different mechanical systems proposed. These systems include an underfloor air delivery (UFA) system and a conventional overhead VAV systems (similar to existing campus buildings' systems). In addition to the cost issues, the indoor air quality, maintenance and flexibility aspects of the systems were addressed.

Mechanical System Operation

The choice of mechanical system has a significant effect on the operational costs, first costs and occupant comfort. This study evaluates the cost effectiveness of a series of different mechanical systems under consideration for the Kavli Building.

SYSTEM DESCRIPTIONS

Underfloor Systems

Underfloor systems change the way conditioned air is delivered to a space with the use of raised floor panels also known as an access floor. By design, this access floor creates a void between the raised floor and the structure, which is used as plenum for supply air, electrical wires and communication cables. Supply air grilles are mounted flush to the floor to maintain a flat floor and walking surface. With this configuration, supply air is provided at the level where the building occupants are as shown in Figure 1. Because the air is distributed at low levels, the delivery temperature is higher than with an overhead system. Most underfloor systems deliver air at 63°F, which allows greater opportunity to "free cool" than with an overhead system delivering air at 55°F. In the configuration proposed for this building, fan coil units are distributed throughout the building to handle any heating loads. In-floor VAV boxes provide zone level control to individual spaces.

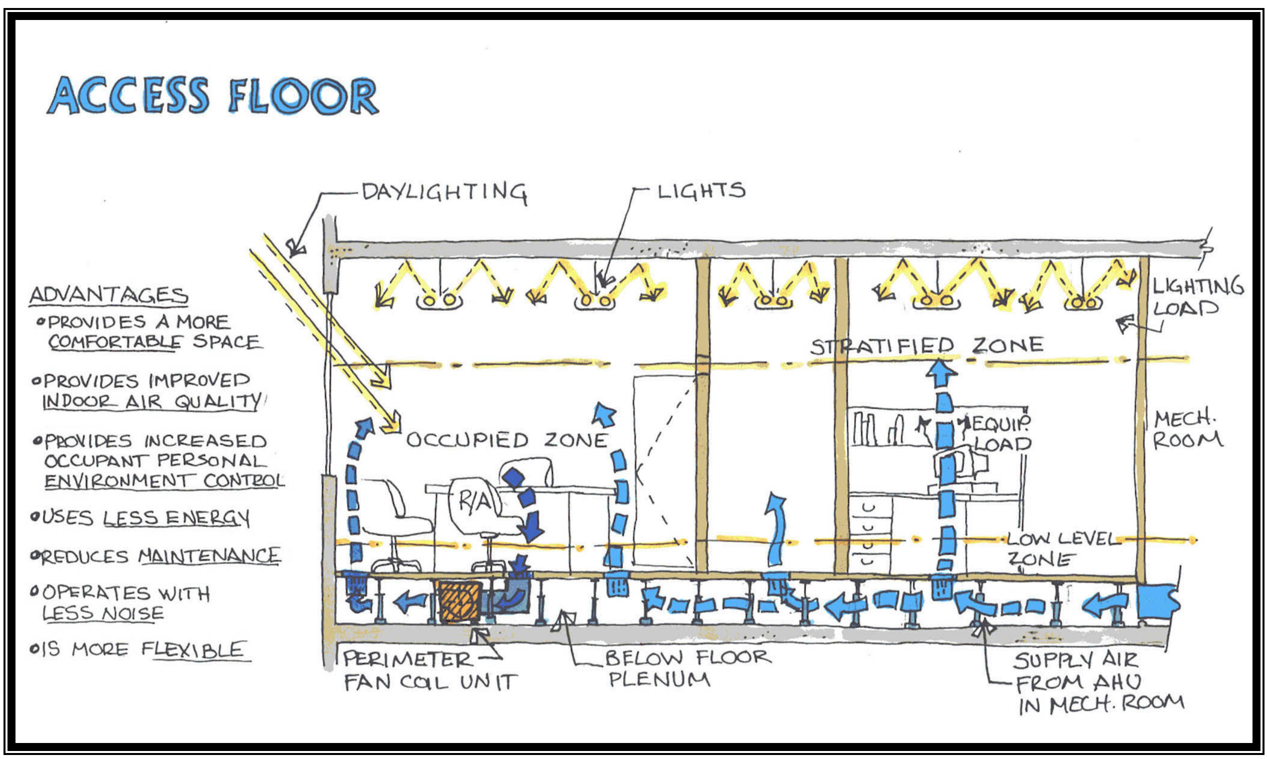

Figure 1: Underfloor Air Delivery System

Overhead VAV System

Overhead VAV systems deliver supply air to building occupants from the ceiling above with diffusers providing mixing action to distribute the new air within the space as shown in Figure 2. As mentioned previously, the air is delivered at 55°F. Thermostats and occupancy sensors control the air volume delivered by each VAV box.

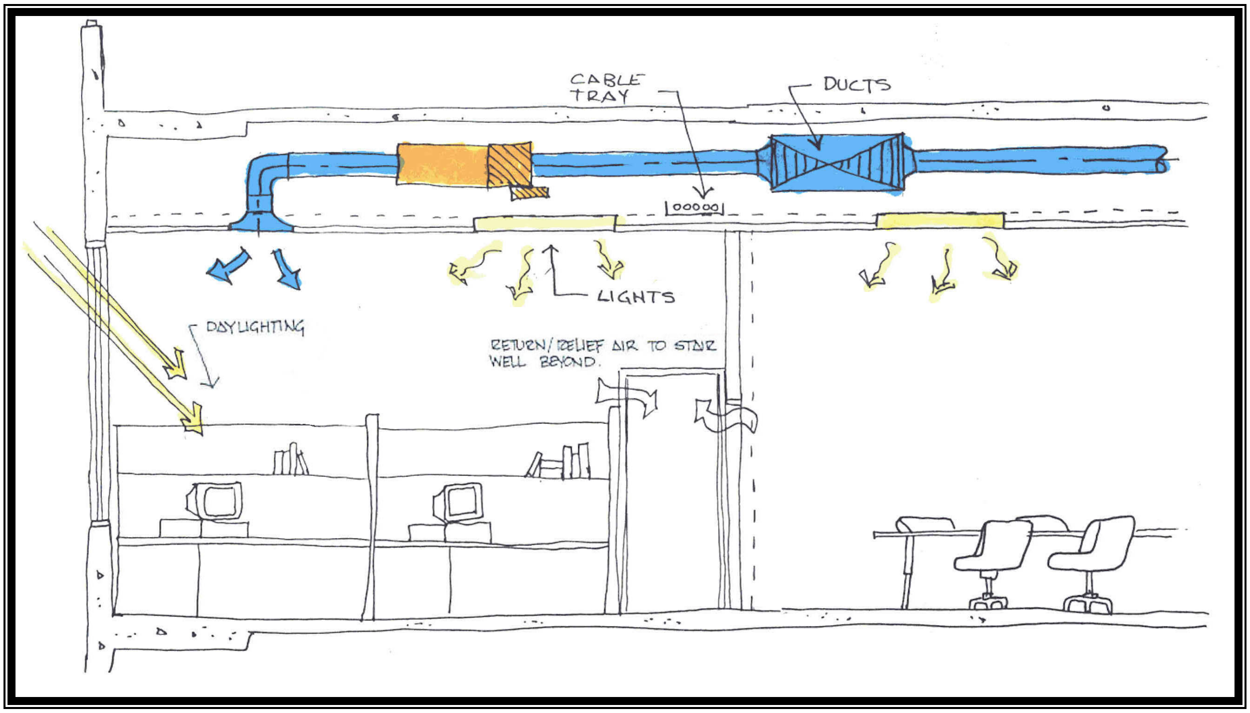

Figure 2: Conventional Air Delivery System

SYSTEM ATTRIBUTES

These two systems vary in terms of the controllability, air quality and flexibility. These attributes are discussed below. Further information on access floor attributes has been included in the appendix for reference.

Occupant Comfort & Control

Generally speaking, both systems will allow for good occupant comfort. Control is achieved in different ways depending on the system.

Control for the underfloor system is achieved through the use of adjustable diffusers. These diffusers are located near (but not directly under) occupants and can easily be adjusted by the occupants themselves. Additional control is achieved through thermostats controlling the perimeter fan coil units and interior VAV boxes. The adjustability of the floor system also allows individual tailoring to a level that is not easy to achieve with a ducted system. It is easy to add or remove diffusers as needed without the use of specialized equipment or technicians. For example, an occupant who tends to feel cooler may choose to locate the supply air diffuser further away from their direct workspace to have fewer diffusers than a person who is frequently warm. Alternatively, the occupant may choose to adjust the diffuser to deliver the minimum volume of air to their immediate workspace. This scenario is reversed for occupants who desire more cool air if they are feeling too warm.

With an overhead system, zone level control is achieved with thermostats that can vary the volume of the supply air to the space. Each VAV box is controlled by a thermostat and a VAV box serves three offices or part of a larger room. Control for individual occupants may also be achieved with operable windows at the perimeter. Occupant sensors can also shut down the VAV systems when they are not needed for the particular zone. Addition or subtraction of diffusers requires specialized technical assistance and cannot be done by the users.

Improved Indoor Air Quality

Both systems provide satisfactory indoor air quality. The US Green Building Council, through the LEED™ system, however, recognizes that underfloor air systems may have better indoor air quality than the other two systems. This improvement is a result of the "new" air being delivered at a level below the occupants instead of above them. Underfloor air systems are more efficient at removing air pollutants because there is less mixing of old air in the space than with conventional overhead delivery systems. As supply air enters the space at the floor level, warm air and air pollutants are stratified and pushed upward and out of the space through return air grilles.

In terms of the ventilation effectiveness in a building, it has been reported that with conventional systems more than 50% of the supplied outside air never reaches the occupied zone. With underfloor air systems, 100% of the supplied outside air is delivered to the occupied zone, thus improving the ventilation effectiveness by at least 50%.

As with all air delivery systems, precautions should be taken to ensure the air delivery path and supply air plenum remain clean, free of mold growth and potential air contaminants.

System Flexibility

The overhead system does not offer the same level of flexibility as the underfloor system. Access floors in particular are allow for more maximum flexibility during staff movement and equipment and wiring changes in building layouts without being restricted by the design of the HVAC and electrical systems. More system flexibility is advantageous for different types of situations such as churn, remodeling, or wiring and equipment changes. This facility, however, may have a low churn rate except, possibly, in the graduate student open office areas so this may not be a significant consideration.

Energy Analysis

A schematic level VisualDOE model was completed on the three systems to compare the energy consumption. The assumptions regarding lighting and envelope were held consistent between models and corresponded to an energy consumption at 20% less than Title 24. This 20% value is conservative compared to what the project is aiming for but the differential will not be significantly different with a greater energy savings goal. A chiller and boiler were assumed in this building at this point in time. Stanford's energy rates were used as per the information available from the Campus Energy Manager.

The results show that there is a potential savings of almost 1.75 kWh per square foot per year. A dollar savings estimate of $4,570 with the underfloor system has been made based on 25,000 square feet of area and $0.135 per kWh for electricity and $1.46 per therm for gas. These results can be seen in Table 3 as well as the following energy pies.

Table 3: Annual Energy Consumption

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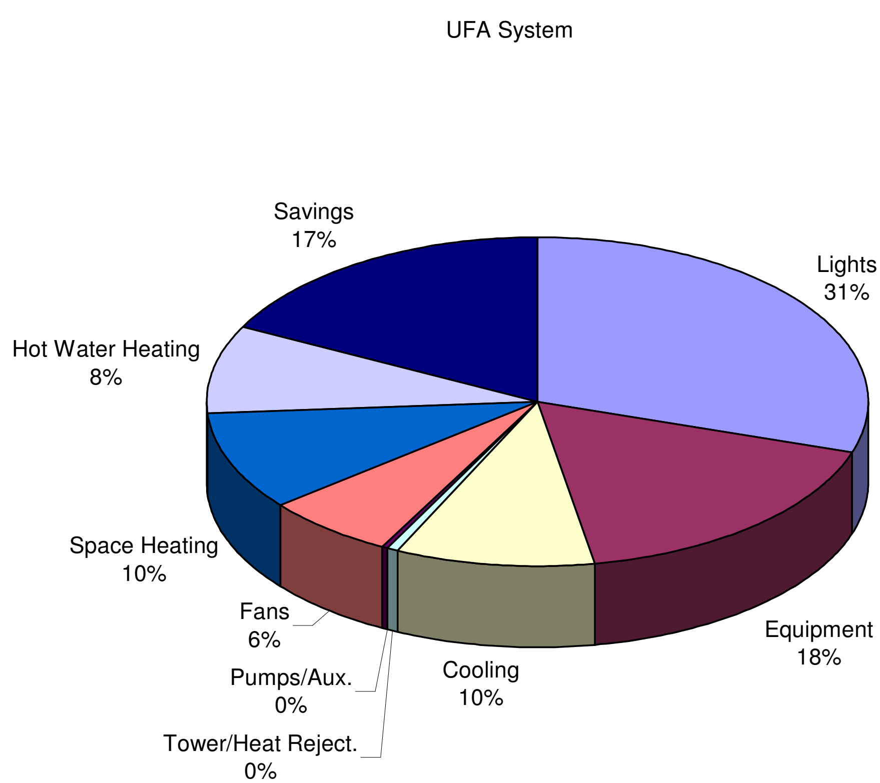

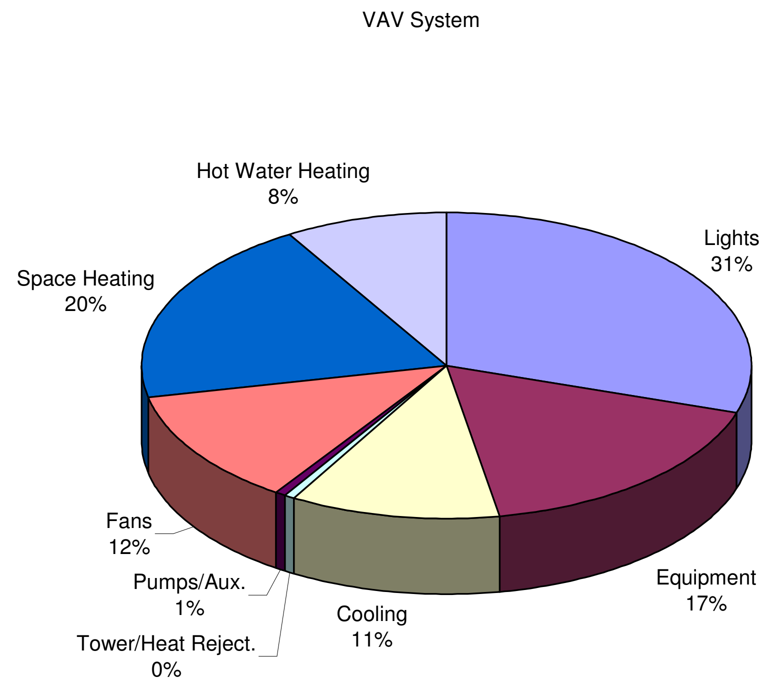

Cost Analysis

A capital cost estimate has been made for both systems by Oppenheim Lewis. This cost analysis is based on the capital costs per square foot. Where not listed, items are assumed to be the same between each case. As can be seen, there is a $\$1.36/ft^2$ difference between the two systems. Additionally, it has been assumed that a ceiling is not necessary for the underfloor air system except in some areas, but there will be some kind of treatment necessary that has been accounted for in the costs in Table 4.

Table 4: Capital Costs per Square Foot

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User Power/Tel. Distribution	2.50	3.00
Lighting	$0.00	$0.00
Total Cost	**$39.08**	**$37.72**

Conclusions and Recommendations

There are several different considerations that must be taken into account when determining the mechanical system to be used in this project. The underfloor air system will be able to provide the flexibility desired for future technology unknowns within the facility and is favorable on an operating cost basis. For this reason, Keen recommends that the users and project team discuss the priorities for the project and determine which option suits the project needs better.