National Renewable Energy Laboratory
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Practical Integration Approach and Whole Building Energy Simulation of Three Energy Efficient Building Technologies

Preprint

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Presented at ASME 2010 4th International Conference on Energy Sustainability (ES2010)
Phoenix, Arizona
May 17–22, 2010

Conference Paper
NREL/CP-550-48125
August 2010

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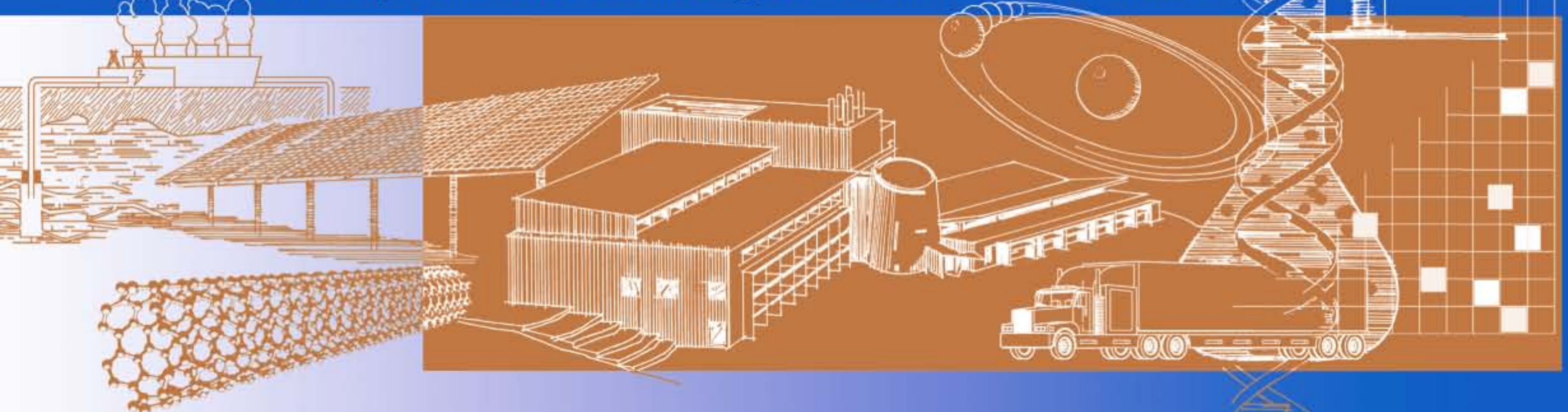

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Proceedings of the ASME 2010 4th International Conference of Energy Sustainability
ES2010
May 17-22, 2010, Phoenix, Arizona, USA

ES2010-90480

A PRACTICAL INTEGRATION APPROACH AND WHOLE BUILDING ENERGY SIMULATION OF THREE ENERGY EFFICIENT BUILDING TECHNOLOGIES

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ABSTRACT

Rising energy costs and the desire to reduce energy consumption dictates a need for significantly improved building energy performance. Three technologies that have potential to save energy and improve sustainability of buildings are dedicated outdoor air systems (DOAS), radiant heating and cooling systems and tighter building envelopes.

Although individually applying innovative technologies may incrementally improve building energy performance, more significant payoffs are realized when compatible technologies are integrated into an optimized system. Fortunately, DOAS, radiant heating and cooling systems and improved building envelopes are highly compatible.

To investigate the energy savings potential of these three technologies, whole building energy simulations were performed for a barracks facility and an administration facility in 15 U.S. climate zones and 16 international locations. The baseline facilities were assumed to be existing buildings with VAV HVAC systems (admin facilities) and packaged HVAC systems (barracks facilities). The energy simulations were adjusted for each location for optimal energy and humidity control performance. The results show that the upgraded facilities realized total building energy savings between 20% and 40% and improved humidity control when compared to baseline building performance.

INTRODUCTION

Building owners and designers are increasingly interested in building energy systems that cost effectively reduce energy consumption and energy costs while maintaining comfort and acceptable indoor air quality. Three technologies that have potential for significant energy savings are dedicated outdoor air systems (DOAS), radiant heating/cooling systems, and tighter building envelopes. While each of these technologies, applied individually, can realize energy savings, it is important to think in terms of a systems approach rather than just applying these technologies individually. For example, radiant cooling systems have the potential to save a great deal of energy when compared to all-air heating/cooling systems, primarily due to a major reduction in fan energy. Unfortunately, major moisture and condensation problems can occur if the space dew point temperature (DPT) is not maintained below the surface temperature of the radiant cooling system components. Tighter building envelopes reduce the heating, cooling and dehumidification energy required to overcome the effects of uncontrolled infiltration of outdoor air. They also reduce the amount of makeup air required to maintain positive pressurization of the building.

BASELINE BUILDING DESCRIPTIONS

To better understand the energy impacts of these technologies, we modeled two building types (an administrative facility and a barracks facility) in fifteen

U.S. climate zones and sixteen international locations using EnergyPlus. Administration and barracks facilities are the two most common building types in the U.S. Army. Admin facilities are similar in many respects to private sector office buildings and barracks facilities bear similarities to many apartment buildings and hotel buildings with interior corridors. For this study, we developed each baseline facility model in compliance with the requirements of ASHRAE Standard 90.1-1989 (ASHRAE 1989) since the Army has a large inventory of existing admin and barracks facilities which were designed and constructed in accordance with this standard and are current candidates for major renovation and upgrade. For each facility type, we developed "improved" facility models which included DOAS and radiant heating/cooling systems and a "further improved" facility model which included DOAS, radiant heating/cooling and a tighter building envelope. Renderings of the baseline facilities are shown in Figs. 1 and 2 below. Technical specifications are provided in Tables 1 and 2.

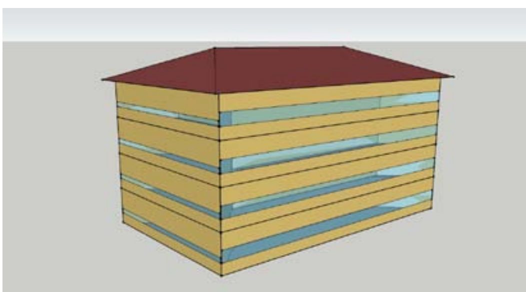

Figure 1. Rendering of modeled administration facility
credit: Kyle Benne/NREL

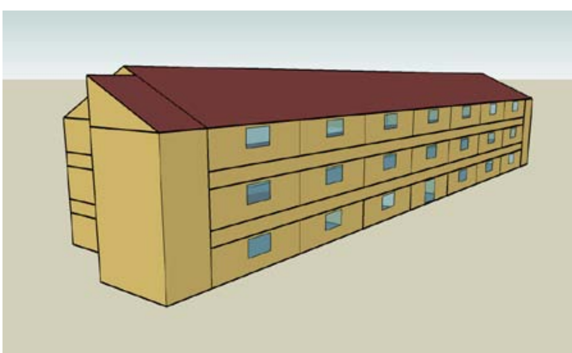

Figure 2. Rendering of modeled barracks facility
credit: Michael Deru/NREL

Table 1. Baseline administrative facility

Building Component	Component Description
Area (total)	23,250 ft^2 (2,160 m^2)
Floors	4
Foot print shape	Rectangle
Fenestration type	Standard 90.1-1989
Wall construction	Steel frame with brick exterior
Wall insulation	Standard 90.1-1989, mass wall
Roof construction	Sloped metal roof with insulation at roof level
Roof insulation	Standard 90.1-1989, with attic
Infiltration	1 cfm/ft^2 (5.08 L/s-m^2) of shell area at 0.3 iwg (75 Pa)
Window-to-wall ratio	Total – 23.44%; North – 30.00%; East – 12.51%; South – 30.00%; West – 12.51%
Temperature set points	75 ˚F (23.9 ˚C) cooling and 70 ˚F (21.1 ˚C) heating with night setback to 86 ˚F (30 ˚C) cooling and 60 ˚F (15.6 ˚C) heating
Ventilation	20 cfm (9.44 L/s) per person
HVAC	VAV system with central chiller (4.5 COP) and natural gas boiler (0.8 Et)
DHW	Natural gas boiler (0.8 Et)

Table 2. Baseline barracks facility

Building Component	Component Description
Area (total)	28,965 ft^2 (2,691 m^2)
Floors	3
Foot print shape	Rectangle
Fenestration type	Standard 90.1-1989
Wall construction	Wood frame with brick exterior
Wall insulation	Standard 90.1-1989, mass wall
Roof construction	Sloped metal roof with Insulation at roof Level
Roof insulation	Standard 90.1-1989, with attic
Infiltration	1 cfm/ft^2 (5.08 L/s-m^2) of shell area at 0.3 iwg (75 Pa)
Window-to-wall ratio	Total – 6.88%; North – 8.91%; East – 0.00%; South – 9.38%; West – 0.00%
Temperature set points	75 ˚F (23.9 ˚C) cooling and 70 ˚F (21.1 ˚C) heating
Ventilation	75 cfm (35.4 L/s) continuous per unit
HVAC	PSZ with DX-AC (2.6 COP) and gas furnace (0.8 Et)
DHW	Natural gas boiler (0.8 Et)

The models assumed that the administrative facility was occupied during typical business hours, five days per week. During unoccupied hours, the system enters night cycle mode where outside ventilation air is shut off and zone temperature controls are set back (set up). The barracks facility models assumed that the heating, cooling and ventilating systems were in occupied mode 24 hours per day, 365 days per year.

The baseline administrative facility used chilled water from an air-cooled chiller and hot water reheat at the VAV terminal units supplied by a central gas boiler.

The floor plan of the barracks facility is similar to an apartment building with each unit designed for occupancy by two soldiers. Temperature control in each baseline barracks unit is handled by a single zone constant speed air system cooled by DX and heated by a natural gas furnace.

IMPROVED BUILDING DESCRIPTIONS

The "improved" admin facility uses radiant heating/cooling panels served by chilled water from an air-cooled chiller and hot water from a gas boiler. A constant volume DOAS provides conditioned ventilation air only during occupied hours. The DOAS supply air temperature is governed by an outside air temperature reset schedule. The DOAS provides minimal sensible heating/cooling through water coils supplied by a gas boiler and a chilled water coil supplied by a second air-cooled chiller. The water loops feeding the DOAS are separate from the radiant system. The primary space sensible load is designed to be met by the radiant heating/cooling system.

The HVAC system for the "improved" barracks facility is essentially the same as for the "improved" administrative facility. The major difference is that the "improved" barracks facility is assumed to be constantly occupied, thus the DOAS system runs continuously. The DOAS system models for both the administrative facility and barracks facility include total energy recovery (TER) to extract energy from the buildings' exhaust air streams.

The "further improved" models for both the administrative facility and the barracks facility incorporate tighter building envelopes in addition to the DOAS system and radiant heating/cooling system in the "improved" models. Tighter building envelopes reduce infiltration from 1.0 cfm/ft^2 (5.08 L/s-m^2) at a reference pressure difference of 75 Pa between the building interior and the outdoor ambient conditions in the baseline facilities to 0.25 cfm/ft^2 (1.27 L/s-m^2) at a 75 Pa pressure difference in the "further improved" models.

SELECTED SIMULATION LOCATIONS AND CORRESPONDING ENERGY COSTS

Fifteen locations were selected to represent fifteen climate zones in the United States. The U.S. locations were selected as representative cities for the climate zones by the Pacific Northwest National Laboratory (Briggs et al. 2003). In addition, 16 locations were selected outside of the U.S. in Canada and Europe. The 15 U.S. and 16 non U.S. locations are shown in Tables 3 and 4. Both tables include the ASHRAE Standard 90.1-1989 table numbers for the locations that were used to select the envelope thermal criteria. The 90.1-1989 tables for the non U.S. locations were selected based on the heating degree days (HDD) and cooling degree days (CDD).

Table 3. U.S. Climate Zones and Cities used for Simulations

Climate Zone	ASHRAE 90.1 – 1989 Table	City	HDD, 65ºF (18.3 ºC)	CDD, 50ºF (10 ºC)
1A	5	Miami, FL	200 (111)	9474 (5263)
2A	10	Houston, TX	1599 (888)	6876 (3820)
2B	12	Phoenix, AZ	1350 (750)	8425 (4681)
3A	15	Memphis, TN	3082 (1712)	5467 (3037)
3B	18	El Paso, TX	2708 (1504)	5488 (3049)
3C	19	San Francisco, CA	3016 (1676)	2883 (1602)
4A	23	Baltimore, MD	4707 (2615)	3709 (2061)
4B	24	Albuquerque, NM	4425 (2458)	3908 (2171)
4C	25	Seattle, WA	4908 (2727)	1823 (1013)
5A	26	Chicago, IL	6536 (3631)	2941 (1634)
5B	28	Boise, ID	5882 (3231)	2716 (1509)
6A	32	Burlington, VT	7771 (4317)	2228 (1238)
6B	33	Helena, MT	7699 (4277)	1841 (1023)
7A	36	Duluth, MN	9818 (5454)	1536 (853)
8A	38	Fairbanks, AK	13940 (7744)	1040 (578)

Flat utility tariffs were assumed for each location (i.e. no energy demand charges are included). The U.S. energy costs are based on flat rates at the average for commercial rates in each state and may not reflect the utility rates at a specific location. A fixed price was assumed for all non U.S. cities as shown in Table 5.

Table 4. Non U.S. Climate Zones and Cities used for Simulations

Climate Zone	ASHRAE 90.1 – 1989 Table	City	HDD, 65°F (18.3 °C)	CDD, 50°F (10 °C)
7	36	Edmonton, CAN	10049 (5583)	1042 (579)
6	33	Ottawa, CAN	8395 (4664)	2014 (1119)
5	19	Vancouver, CAN	5436 (3020)	1451 (806)
5	28	Stuttgart, DEU	6008 (3338)	2340 (1300)
5	28	Copenhagen, DNK	6413 (3563)	1283 (713)
7	33	Helsinki, FIN	8482 (4712)	1039 (577)
7	33	Tampere, FIN	9036 (5020)	950 (528)
4	20	Lyon, FRA	4570 (2539)	2669 (1483)
4	3	Marseille, FRA	3123 (1735)	3789 (2105)
4	4	Nantes, FRA	4057 (2254)	2360 (1311)
4	19	Paris, FRA	4759 (2644)	2176 (1209)
4	19	London, GBR	5159 (2866)	1555 (864)
4	25	Milan, ITA	4750 (2639)	2947 (1637)
4	9	Naples, ITA	2455 (1364)	4473 (2485)
2	9	Palermo, ITA	1303 (724)	5805 (3225)
4	24	Rome, ITA	2599 (1444)	4199 (2333)

Table 5. Energy rates used in simulations

City	Electricity Cost $/kWh	Natural Gas Cost ($/Million Btu)
Miami, FL	$0.0761	$11.44
Houston, TX	$0.0787	$8.42
Phoenix, AZ	$0.0724	$8.71
Memphis, TN	$0.0706	$9.63
El Paso, TX	$0.0787	$8.42
San Francisco, CA	$0.1160	$8.50
Baltimore, MD	$0.0753	$9.23
Albuquerque, NM	$0.0738	$8.19
Seattle, WA	$0.0620	$9.40
Chicago, IL	$0.0752	$9.82
Boise, ID	$0.0537	$8.54
Burlington, VT	$0.1142	$8.76
Helena, MT	$0.0740	$9.64
Duluth, MN	$0.0630	$8.36
Fairbanks, AK	$0.1100	$4.08
All non U.S. cities	$0.0929	$10.67

U.S. MODELING RESULTS – ADMIN FACILITY

Figures 3 through 5 show the electrical, gas and total energy consumption results for the baseline and "improved" administration facility. In all cases, except San Francisco, the addition of DOAS and radiant heating/cooling resulted in decreased electrical consumption. The reduced electrical consumption was most evident in hot or hot/humid locations (i.e., Miami, Houston, Phoenix and El Paso).

Figure 4 shows significant gas energy savings in the cooler and cold locations. This would appear to be a result of the greater efficiency of radiant heating systems than all-air systems.

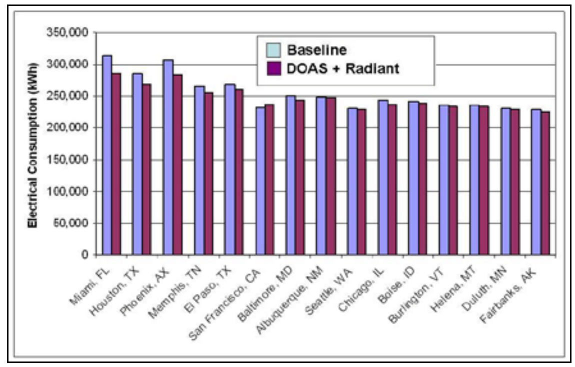

Figure 3. Admin - electrical consumption

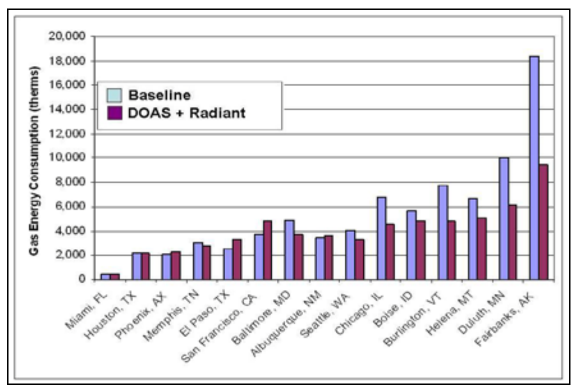

Figure 4. Admin - gas energy consumption

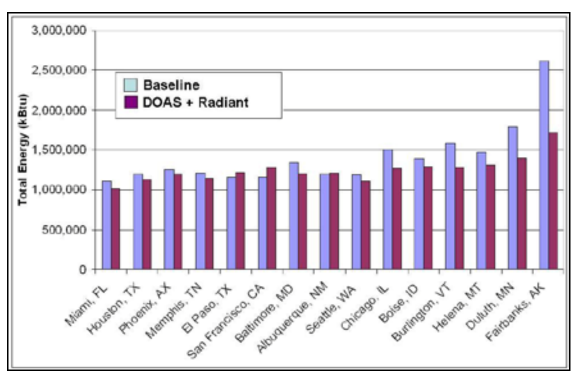

Figure 5. Admin - total energy consumption

Figure 5 indicates that the DOAS + Radiant systems save energy in most climate locations. In El Paso, San Francisco, and Albuquerque the “improved” system appears to consume more energy than the baseline system. This is further illustrated in Fig. 6 where these locations have negative energy savings. Other locations in Fig. 6 show substantial energy savings, especially in the cooler/cold locations.

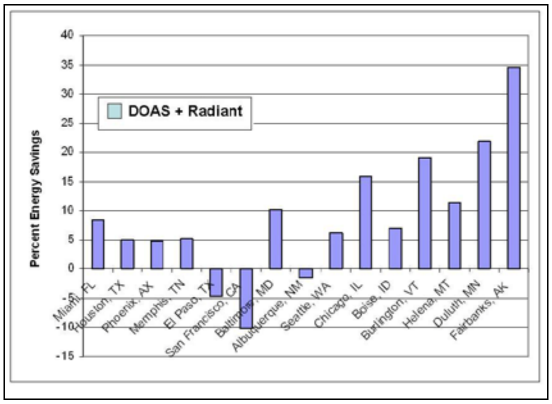

Figure 6. Admin - percent energy savings

Figure 7 illustrates the difference in air flow required by the baseline admin facilities as compared to the “improved” facilities using DOAS + radiant heating/cooling systems. The baseline facilities deliver conditioned air to not only ventilate the building but also to control space temperature. By handling space temperature control through the radiant systems, considerable reduction in air flow rates is possible.

Figures 8 through 12 show modeled results for the barracks facility, including both the “improved” case (i.e., DOAS and radiant heating/cooling) and the “further improved” case (i.e., DOAS plus radiant heating/cooling plus tighter building envelope). In Fig. 8, one can see that both improved systems showed significant electrical energy reductions in most U.S. locations. This is especially interesting when comparing the barracks facility results in Fig. 8 with the administration facility results in Fig. 3.

Very significant gas energy savings are shown in Fig. 9, especially in cooler/cold locations. There is also a significant reduction in gas energy consumption in the buildings with improved envelopes as compared to the buildings with DOAS and radiant only. This would seem to be due to decreased heating loads resulting from diminished infiltration of cold air as a result of improved building envelopes.

Figure 10 shows the total energy consumption performance of the baseline, “improved” and “further improved” barracks facilities.

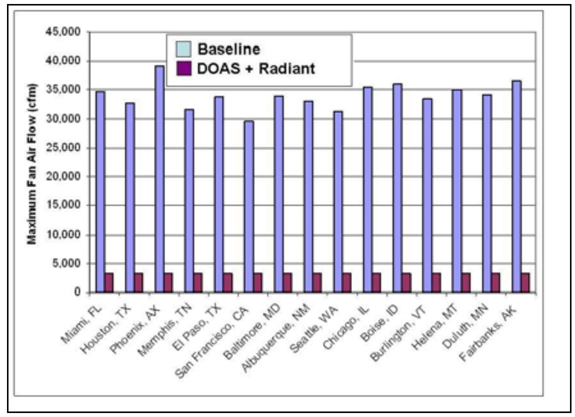

Figure 7. Admin - maximum air flow (cfm)

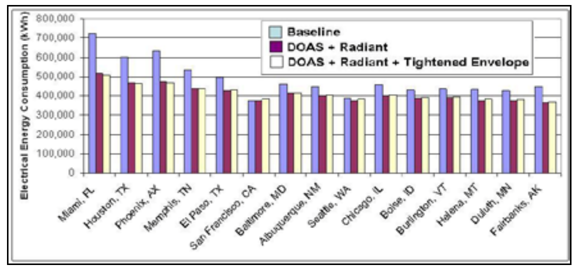

Figure 8. Barracks – electrical energy consumption

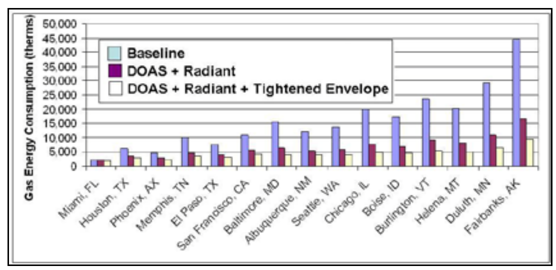

Figure 9. Barracks – gas energy consumption

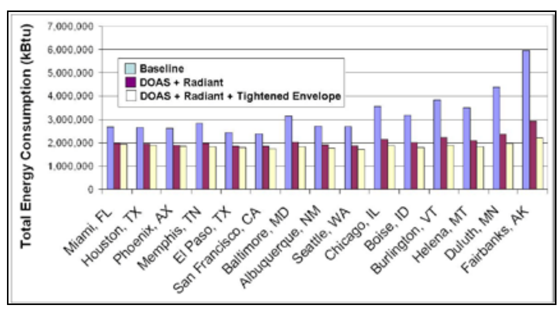

Figure 10. Barracks – total energy consumption

In Fig. 11 one can see that the “improved” and “further improved” barracks facilities save considerable energy over the baseline facilities.

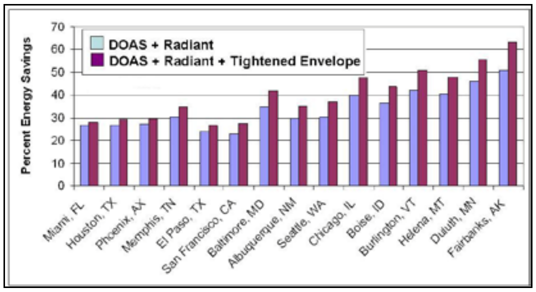

Figure 11. Barracks – percent energy savings

Figure 12 illustrates the difference in air flow required by the baseline barracks facilities as compared to the "improved" and "further improved" facilities. As with the administration facilities, the baseline barracks facilities deliver conditioned air to not only ventilate the building but also to control space temperature. By handling space temperature control through the radiant systems, considerable reduction in air flow rates (and related fan energy) is achieved.

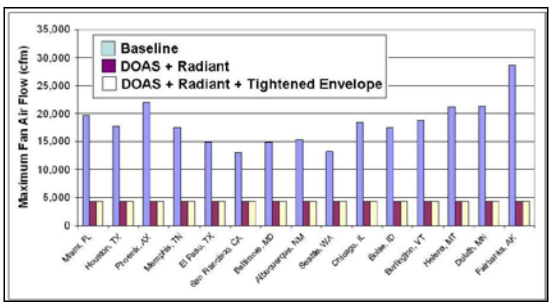

Figure 12. Barracks – maximum fan air flow (cfm)

INTERNATIONAL MODELING RESULTS

Similar simulations were performed for the administration building in sixteen international locations. In Fig. 13, one can see that the "improved" administration facility had significantly reduced electrical energy consumption in all locations when compared to the baseline facility. However, the electrical savings appeared to be achieved at the expense of an increase of gas usage in most locations as shown in Fig. 14. Nevertheless, when electrical and gas energy consumption was calculated, the total energy of the "improved" administration facilities was less than for the baseline facility at all locations as shown in Fig. 15. Figure 16 shows that the "improved" systems realized significant energy savings, ranging from a low of 8% (Paris) to 48% (Stuttgart).

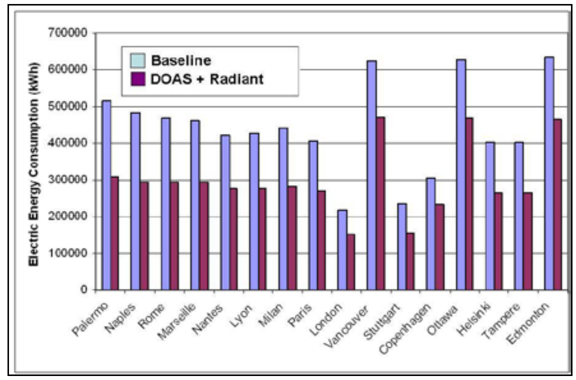

Figure 13. Admin – electrical energy consumption

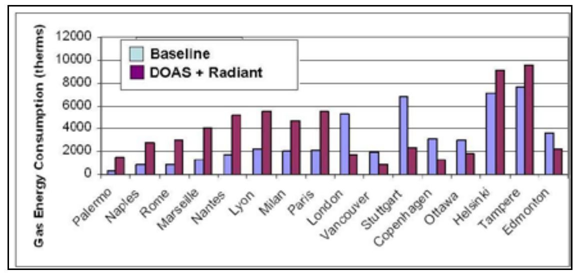

Figure 14. Admin – gas energy consumption

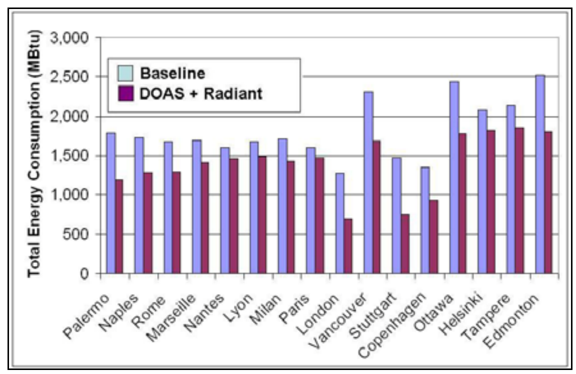

Figure 15. Admin – total energy consumption

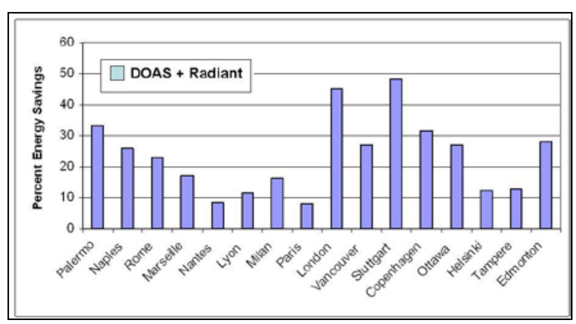

Figure 16. Admin – percent energy savings

Figures 17 and 18 show the annual energy cost savings for U.S. and non U.S. locations.

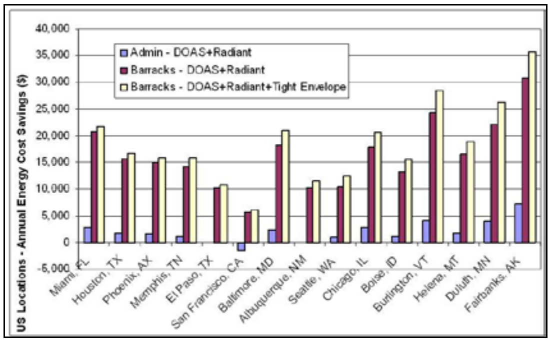

Figure 17. Annual energy cost savings – US locations

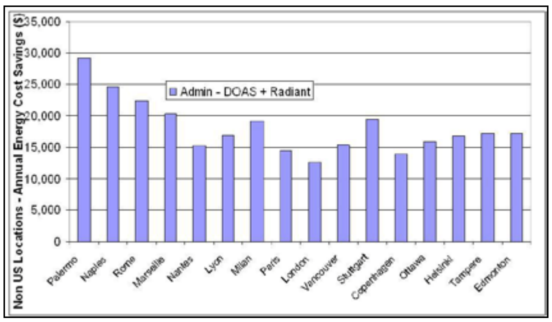

Figure 18. Annual energy cost savings – Non US locations

ECONOMIC CONSIDERATIONS

In most instances, it would be hard to justify the costs of performing a major facility renovation if one's primary motivation for the project was energy conservation. However, in the case of a major facility renovation project, enhanced efficiency features can make good economic sense.

The U.S. Army recently conducted a study at Fort Irwin, CA, to identify possibilities of transitioning the Army towards Net Zero Energy installations. A group of five barracks facilities (each about 25 years old and similar in size and configuration to the barracks facility modeled in this study) were included in the Fort Irwin study. These buildings were studied to determine optional approaches to upgrading the facilities to significantly improve their energy performance.

Under the Army's Barracks Upgrade Program (BUP), barracks facilities typically become eligible for major upgrades at about 25 years of age. A typical upgrade project would normally include complete interior renovation and improving the building envelope with tighter fitting, better insulated doors and more energy efficient windows. Lighting, mechanical systems and appliances are also replaced. Typically, a newly upgraded barracks facility will realize about 8% electrical energy savings and 7% heating energy savings. Although not insignificant, this is not very satisfactory when one considers the amount of money invested in the barracks upgrade project, particularly when one's ultimate goal is to move towards a Net Zero Energy installation.

In a typical barracks upgrade project, existing two-pipe fan coil units and makeup air units are replaced in kind. In the Fort Irwin study, four optional approaches to upgrading the mechanical systems were explored. These optional systems include:

- Option 1 - VAV DOAS with Direct Evaporative Cooling
- Option 2 – VAV DOAS system with Radiant Heating/Cooling (including direct and indirect evaporative cooling)
- Option 3 – VAV DOAS system with Fan Coils (including direct and indirect evaporative cooling)
- Option 4 - VAV DOAS with Direct and Indirect Evaporative Cooling

Cost estimates for the baseline mechanical system and each of the optional mechanical systems were prepared. Of the four optional approaches investigated in the Fort Irwin study, Option 2 is most similar to the "improved" system discussed in this study. As a result, the estimated costs of a typical mechanical system upgrade and a DOAS system with radiant heating/cooling (including direct and indirect evaporative cooling) are compared in Table 6 below. In Table 7, other work elements common to a typical barracks upgrade project and an upgrade project performed in accordance with Option 2 are compared.

Table 6. Comparison of estimated retrofit costs

Typical Upgrade Project	Option 2 Approach	Mechanical System Elements
	$10,000	DOAS-VAV AHU with Direct Evap cooling
	$20,000	Indirect evaporative coolers
	$35,000	Pad/Equipment enclosure for external equipment
	$10,000	Duct riser from equipment enclosure into building
	$15,000	Electrical power to equipment pad
$35,000	$35,000	CHW Piping to AHU dynamic 2 pipe switchover
$18,000	$18,000	Ductwork for toilet exhaust system
$5,000	$5,000	Electrical for exhaust fan system
$30,000	$45,000	3 Fan Coil Units for other spaces (game room, laundry, misc) (Larger for RHC system due to 60°F CHWS temps)
	$12,000	Indirect evap cooler related controls/monitoring
$18,000	$18,000	Heating/cooling switchover controls - dynamic - load based
$30,000	$30,000	Exhaust system modifications in rooms - add manual dampers
$6,000	$6,000	Exhaust system modifications at roof - 1 EF/controls
	$64,800	Insulate existing make-up air duct – re-use for DOAS distribution

$30,000	$30,000	Ducting in rooms for DOAS – Radiant to diffuser
$50,400		Create closets for Fan Coil Units
$86,400		Install Fan Coil Unit access doors
	$40,000	DOAS AHU Controls/monitoring equipment
$17,000	$17,000	Automatic Heating/Cooling switchover valves and controls
$4,320	$4,320	New room supply air diffusers
	$25,000	Toilet exhaust system heat recovery
	$24,000	Radiant heating/cooling (RHC) room controls/DDC thermostat heating and cooling – switchover
	$8,000	RHC water temp mixing controls
	$20,000	RHC circulating pump system and VFD/controls
	$94,400	RHC panels system
	$38,800	RHC attachment to ceiling (provide ceiling for third floor)
	$400,000	RHC piping to each unit (larger than existing piping)
$458,200		144 two-pipe FCUs (nominal 1/2 ton each, derated to use 50°F/68°F CHWS/CHWR temperatures)
$400,000		Piping to FCUs
$338,400		DDC controls for FCUs
$1,526,720	**$1,025,320**	**Subtotal**
$152,672	$102,532	Mech Contractor Overhead @10%
$152,672	$102,532	Mech Contractor Profit @10%
$152,672	$102,532	General Contractor Fee @10%
$1,984,736	**$1,332,916**	**Subtotal, hard costs**
$317,558	$213,267	COE Admin @ 16%
$198,474	$133,292	Mech Engineering @10%
$59,542	$39,987	Elec Engineering @ 3%
$59,542	$39,987	Controls Engineering @ 3%
$19,847	$13,329	Struct Engineering @ 1%
$99,237	$66,646	Constr Management @ 5%
$99,237	$66,646	Proj Management @ 5%
$59,542	$39,987	Travel related expenses, all disciplines @ 3%
$138,932	$93,304	Commissioning (all onsite, no remote) @ 7%
$1,051,910	**$706,445**	**Subtotal, soft costs**
$3,036,646	**$2,039,361**	**Project Subtotal**
$455,497	$305,904	Unseen conditions multiplier @ 15%
$455,497	$305,904	Project escalation due to future installation date @ 15%
$455,497	$305,904	Remote site multiplier @ 15%
$4,403,137	**$2,957,074**	**System Total**

Perhaps surprisingly, the Fort Irwin Option 2 system (DOAS, radiant heating/cooling, direct/indirect evaporative cooling) is estimated to be significantly less expensive to install than the conventional HVAC system using fan coil units and makeup air units. Although this Option 2 system is not identical to the system simulated in our modeled barracks facility, it is sufficiently similar to suggest that the "improved" version of the modeled facility (DOAS with radiant heating and cooling) should be a less costly alternative than the conventional HVAC system it replaced. That being the case, the "improved" system is the obvious choice for the modeled barracks facility since it not only has a lower first cost but also superior energy performance.

Table 7. Comparison of estimated retrofit costs common to both systems

Typical Upgrade Project	Option 2 Approach	Other Common Work Elements
$91,000	$200,000	R-40 roof insulation
$79,000	$79,000	R-18 Wall insulation
$107,000	$107,000	Double Pane, Low E, Operable windows
$277,000	**$386,000**	**Subtotal**
$27,700	$38,600	General Contractor Fee - Army @ 10%
$304,700	**$424,600**	**Subtotal, hard costs**
$48,752	$67,936	COE Administration @ 16%
$3,047	$4,246	Mechanical Engineering @ 1%
$15,235	$21,230	Electrical Engineering @ 5%
$9,141	$12,738	Controls Engineering @ 3%
$9,141	$12,738	Structural Engineering @ 3%
$15,235	$21,230	Construction Management @ 5%
$15,235	$21,230	Project Management @ 5%
$9,141	$12,738	Travel related expenses, all disciplines @ 3%
$15,235	$21,230	Commissioning (all onsite, no remote) @ 5%
$140,162	**$195,316**	**Subtotal, soft costs**
$444,862	**$619,916**	**Project Subtotal**
$66,729	$92,987	Unseen conditions multiplier @ 15%
$66,729	$92,987	Project escalation due to future installation date @ 15%
$66,729	$92,987	Remote site multiplier @ 15%
$645,050	**$898,878**	**System Total**
Base Case	$253,828	Incremental Cost Difference for Net-Zero Energy Facility Modifications

Having established that, for a major barracks upgrade project, replacing the conventional HVAC system with an "improved" system is a better investment than replacing the existing conventional HVAC system with a similar system, one should consider whether to "further improve" the facility with an enhanced building envelope.

After completion of a Barracks Upgrade project, barracks facilities have an envelope air leakage rate of approximately 0.4 CFM/ft^2 at 0.3 iwg (75 Pa). From our experience, we have found that further reducing the leakage rate to 0.25 CFM/ft^2 at 0.3 iwg (75 Pa) can be accomplished for about \$0.50/ft^2 (\$5.38/m^2). For the barracks facilities, this would add about $12,000 to the project costs which is about 0.37% of the total project cost.

By studying Fig. 17, one can compare the $12,000 additional cost of "further improving" the building envelope to 0.25 CFM/ft^2 at 0.3 iwg (75 Pa) with the additional simulated annual energy savings of making this improvement. For Fairbanks, AK, for example, the additional annual energy savings of further tightening the building envelope of a barracks facility is about $5000, yielding a simple payback of this further improvement to be less than 2.5 years. Warmer climate locations are not expected to yield such short payback periods.

Similar cost estimates were not performed for the simulated administration facility, so no effort will be made to provide a detailed discussion of the economic payback of a project to “improve” or “further improve” such facilities. Nevertheless, given that the cost estimate for upgrading the barracks facilities indicates that the DOAS with radiant heating/cooling and direct/indirect evaporative cooling should be less expensive than the traditional barracks upgrade project, it seems reasonable to expect that this may also be true for a major upgrade of an administration facility.

CONCLUSIONS

Retrofit of existing buildings with innovative technologies may not be economically viable if one is contemplating a project primarily for the sake of energy conservation. However, if a major renovation project is being planned, one should compare the delta (premium) costs of advanced technologies against the additional energy efficiency realized by the advanced technologies versus the costs and energy performance of conventional retrofit technologies. In many cases, this analysis will demonstrate the wisdom of investing a bit more money in more advanced technologies in order to realize substantial energy cost savings.

In this study, incorporating innovative technologies into major facility upgrade projects was shown to have potential for significant energy performance improvements and may actually cost less than conventional “tried and true” approaches. For example, DOAS systems, when combined with radiant heating/cooling systems and tight building envelopes have significant potential to economically save energy while maintaining comfort. Depending on location, additional sealing of the building envelope may also be cost effective.

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. **REPORT DATE** *(DD-MM-YYYY)*	2. **REPORT TYPE**	3. **DATES COVERED** *(From - To)*
August 2010	Conference Paper	

4. **TITLE AND SUBTITLE** Practical Integration Approach and Whole Building Energy Simulation of Three Energy Efficient Building Technologies: Preprint	5a. **CONTRACT NUMBER** DE-AC36-08-GO28308
	5b. **GRANT NUMBER**
	5c. **PROGRAM ELEMENT NUMBER**
6. **AUTHOR(S)** J.P. Miller, M. Deru, K. Benne, A. Zhivov, and D. Heron	5d. **PROJECT NUMBER** NREL/CP-550-48125
	5e. **TASK NUMBER** WF5N1000
	5f. **WORK UNIT NUMBER**
7. **PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393	8. **PERFORMING ORGANIZATION REPORT NUMBER** NREL/CP-550-48125
9. **SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**	10. **SPONSOR/MONITOR'S ACRONYM(S)** NREL
	11. **SPONSORING/MONITORING AGENCY REPORT NUMBER**

12. **DISTRIBUTION AVAILABILITY STATEMENT**
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. **SUPPLEMENTARY NOTES**

14. **ABSTRACT** *(Maximum 200 Words)*
Three technologies that have potential to save energy and improve sustainability of buildings are dedicated outdoor air systems, radiant heating and cooling systems and tighter building envelopes. To investigate the energy savings potential of these three technologies, whole building energy simulations were performed for a barracks facility and an administration facility in 15 U.S. climate zones and 16 international locations.

15. **SUBJECT TERMS**
dedicated outdoor air system; radiant heating; radiant cooling; building envelope

16. **SECURITY CLASSIFICATION OF:**			17. **LIMITATION OF ABSTRACT**	18. **NUMBER OF PAGES**	19a. **NAME OF RESPONSIBLE PERSON**
a. **REPORT**	b. **ABSTRACT**	c. **THIS PAGE**			
Unclassified	Unclassified	Unclassified	UL		19b. **TELEPHONE NUMBER** (*Include area code*)