Integrated Innovative HVAC & SWAC: The Next Generation

DOAS/Radiant Cooling System Integrated with Seawater Air-Conditioning Results in Unparalleled HVAC Approach for the Hawaiian Islands

Combining High-Energy Savings and Superior Indoor Air-Quality HVAC

Presentation at the Rebuild Hawaii Consortium

Sept 20, 2003

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Presentation in two parts:

1. Urgency to adopt energy efficient technology; review of the current and near future availability of energy
2. Radiant Cooling and Dedicated Outdoor Air Management Systems: Presentation of innovative and proven technologies and approaches of how to lower energy use in air-conditioning

Part 1 of Presentation :

Urgency to adopt energy efficient technology; review of the current and near future availability of energy

This part of the presentation gives evidence that implementing energy efficient technologies and approaches are just not only a "good idea" but business and social imperatives

As we are at a historic threshold to a lower-energy way of living we have to change the way we are designing and building systems, such as air-conditioning. The technology and design knowledge exists – we have to change in how we act as designers, operators and consumers of energy intensive technology

Implementing new technology :

Technology AND People

Change can be facilitated by appropriate communication and supportive process

Change includes overcoming ..

- Human reactions; most crucial reactions are …. fear and resistance
- Leadership issues ..
- Roles of people involved in the change
- ………

Important issue to overcome group and personal resistance … **Motivation** to change which

… **Motivation** to change is crucial .. People have to buy in … **Motivation** includes the following steps:

1. Creating a sense of **urgency**
2. Establish **enthusiasm**
3. Involve the people by giving them **ownership of** the process
4. **Rewards** (intrinsic and extrinsic)

Creating **Urgency** in conjunction with energy and resource management issues:

What is our situation in regard to the available energy supply?

All OK and business as usual??

OR

Is there an urgent need to rethink our approach to use energy and other natural resources??

…any idea ?? Your opinion?

Forecasts: **Source EIA, 2001**

Consumption of oil today	76 million barrels per day
Consumption of oil in 2020	~114 millions barrels per day = ~ + **40%** in oil consumption by 2020

Predictions (taken from recent study (2003) about energy future of Hawaii) …

- …cheap fossil fuels will be plentiful and will be available for the next several decades…
- … oil prices will remain between $ 25.00 and $28.00 …for the next decades
- … renewable energies will not be cost competitive ….

Recent study about the future energy in Hawaii, 2003

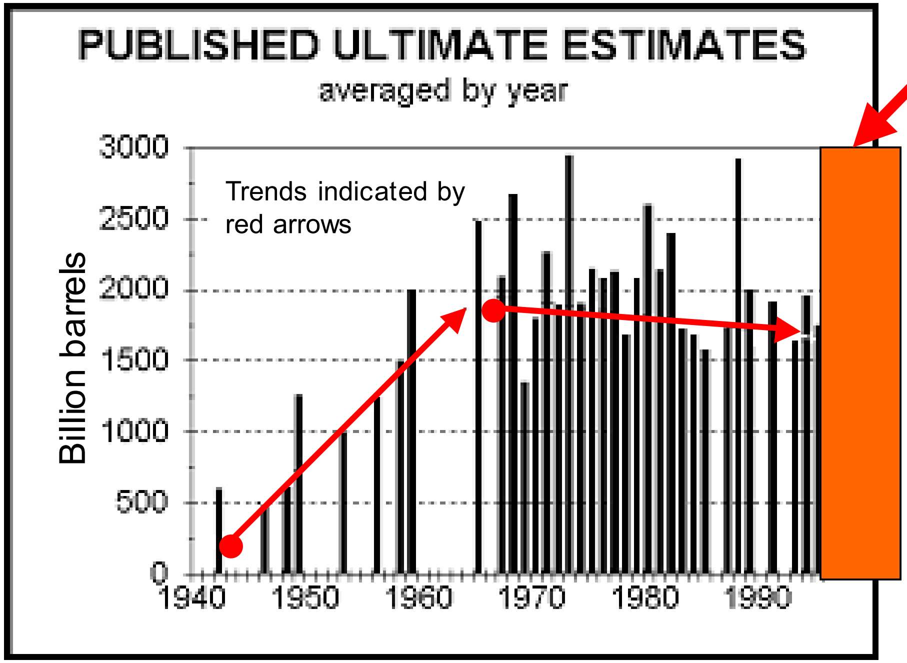
There are alternative sources of information which predict that the future availability of oil will not be abundant and ….cheap

It is worthwhile to consider the statements of these experts

…Oil is the most important form of energy used to today and the global economy depends on it

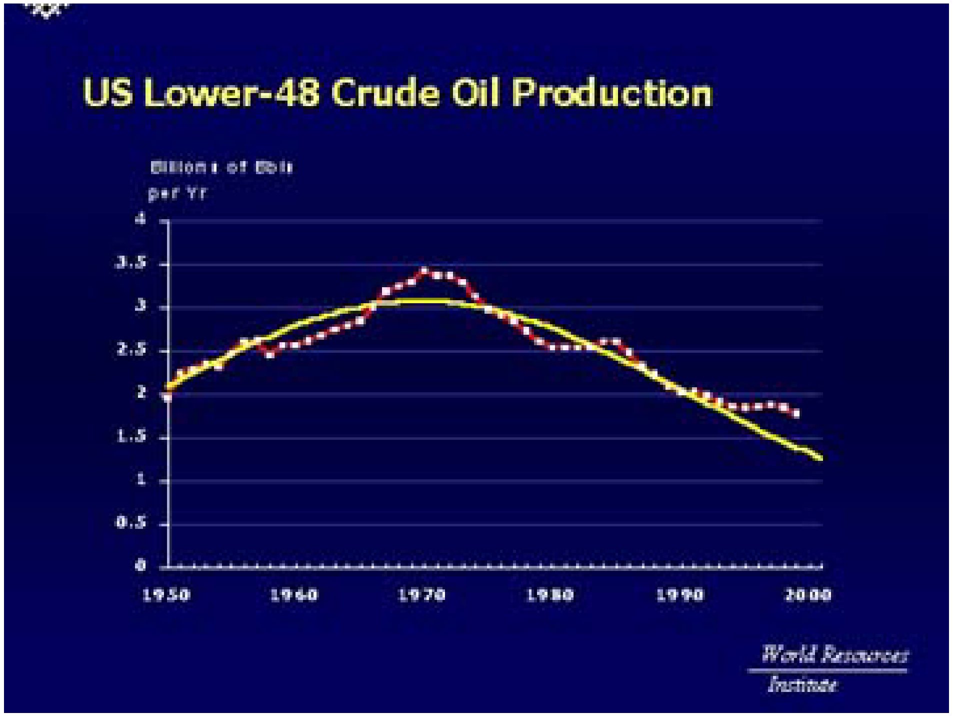
Estimates of Ultimately Recoverable (EUR) Oil Reserves

USGS (2000) predictions of EUR increased from 2200 bb to about 3000 bb in the year 2003



About 950 billion barrel used until today .. with an average EUR of 2000 bb, 1050 bb is left in the ground

BUT ….

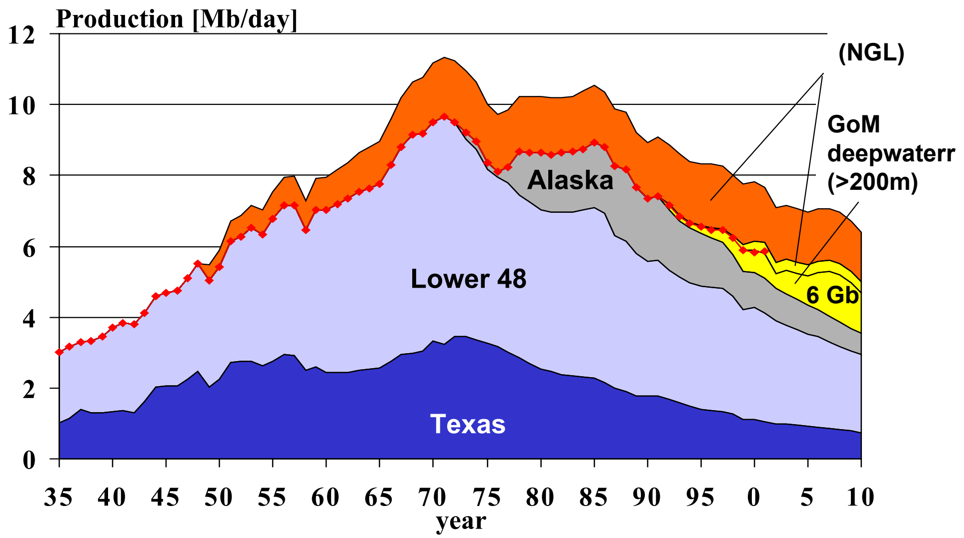


“Hubberts Peak” of Oil Production

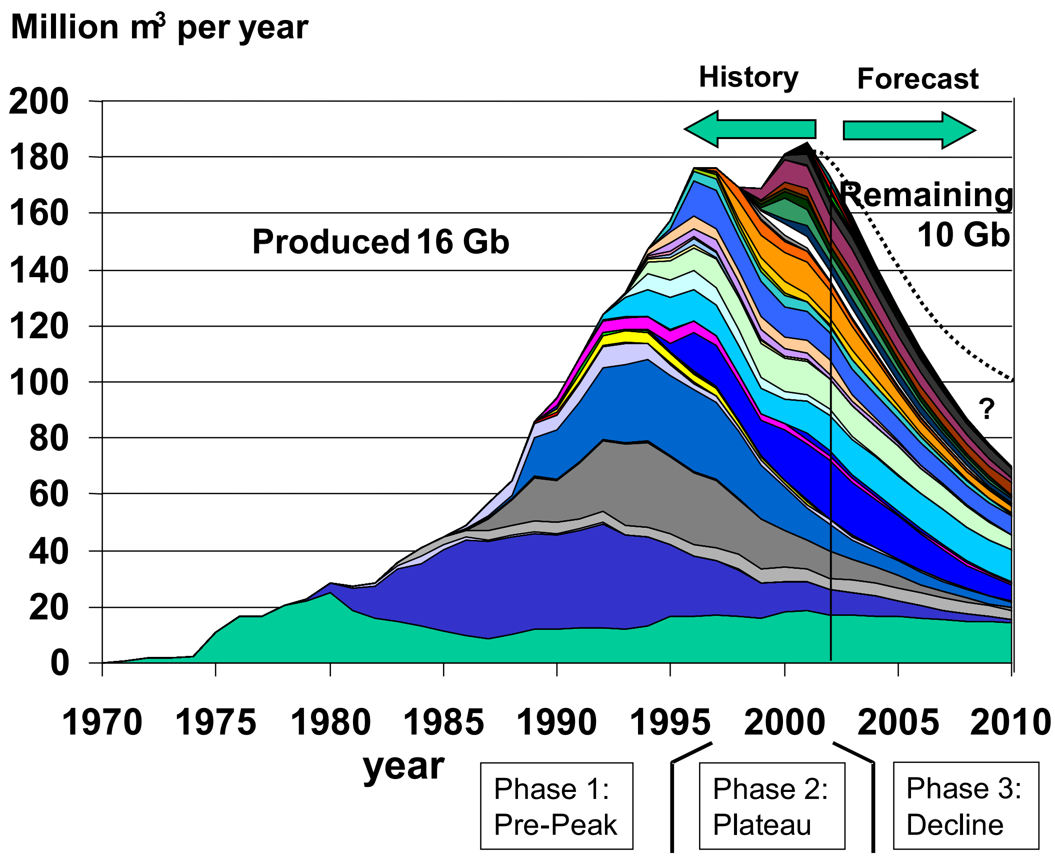
In 1956 Hubbert predicted a peak in oil production for the lower 48 US states to happen in 1970 … it happened in 1970

Hubbert’s model and prediction approach can be applied to the global oil supply …

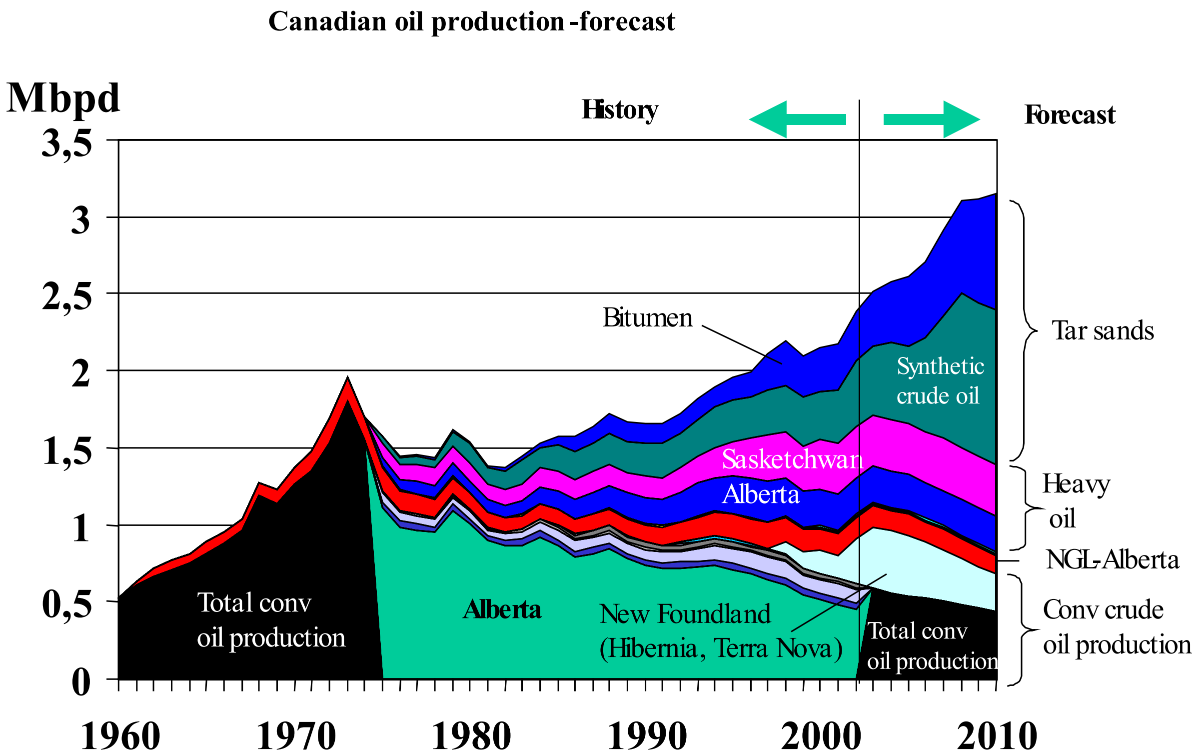
Oil supply USA (1935-2010) - Forecast



Oil Production in the US (including Alaska)



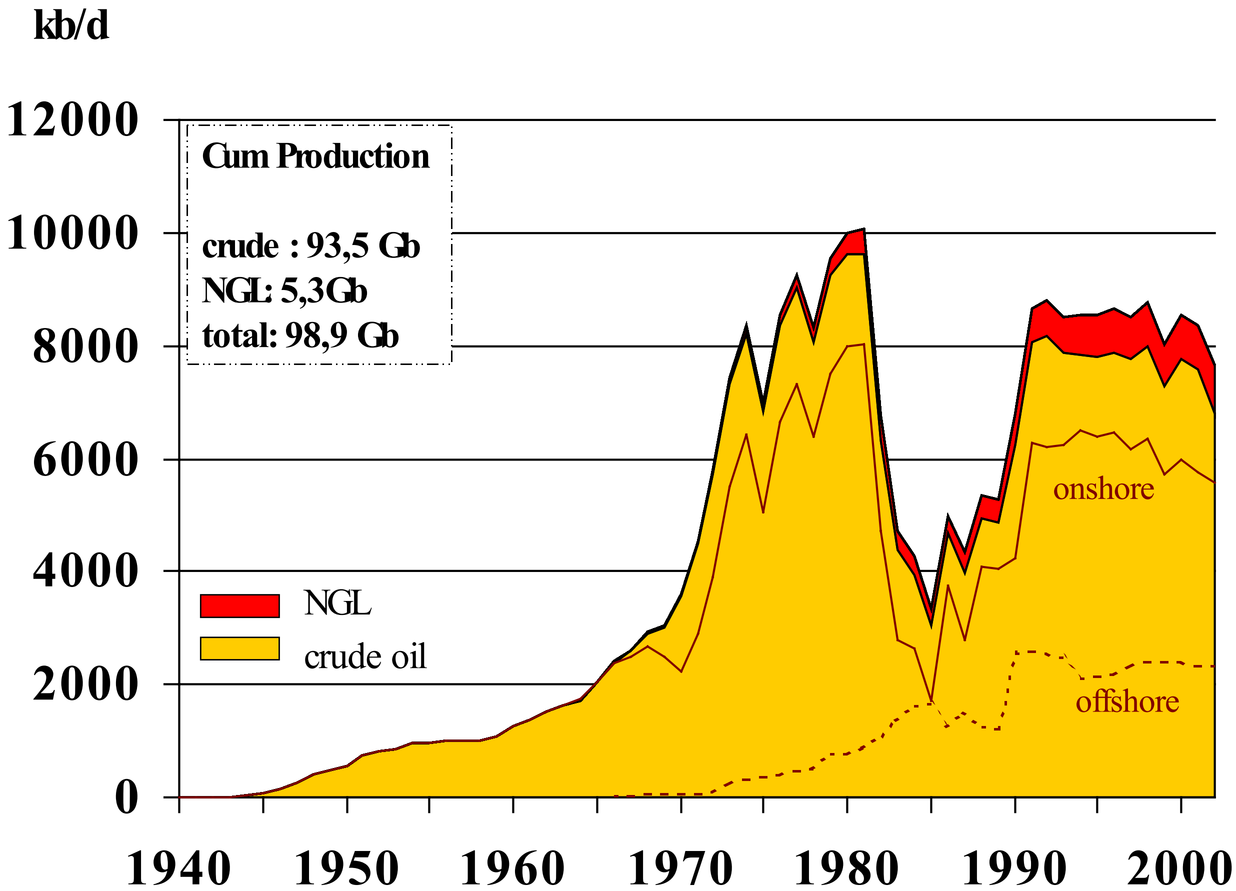
Oil production in the UK (past peak)



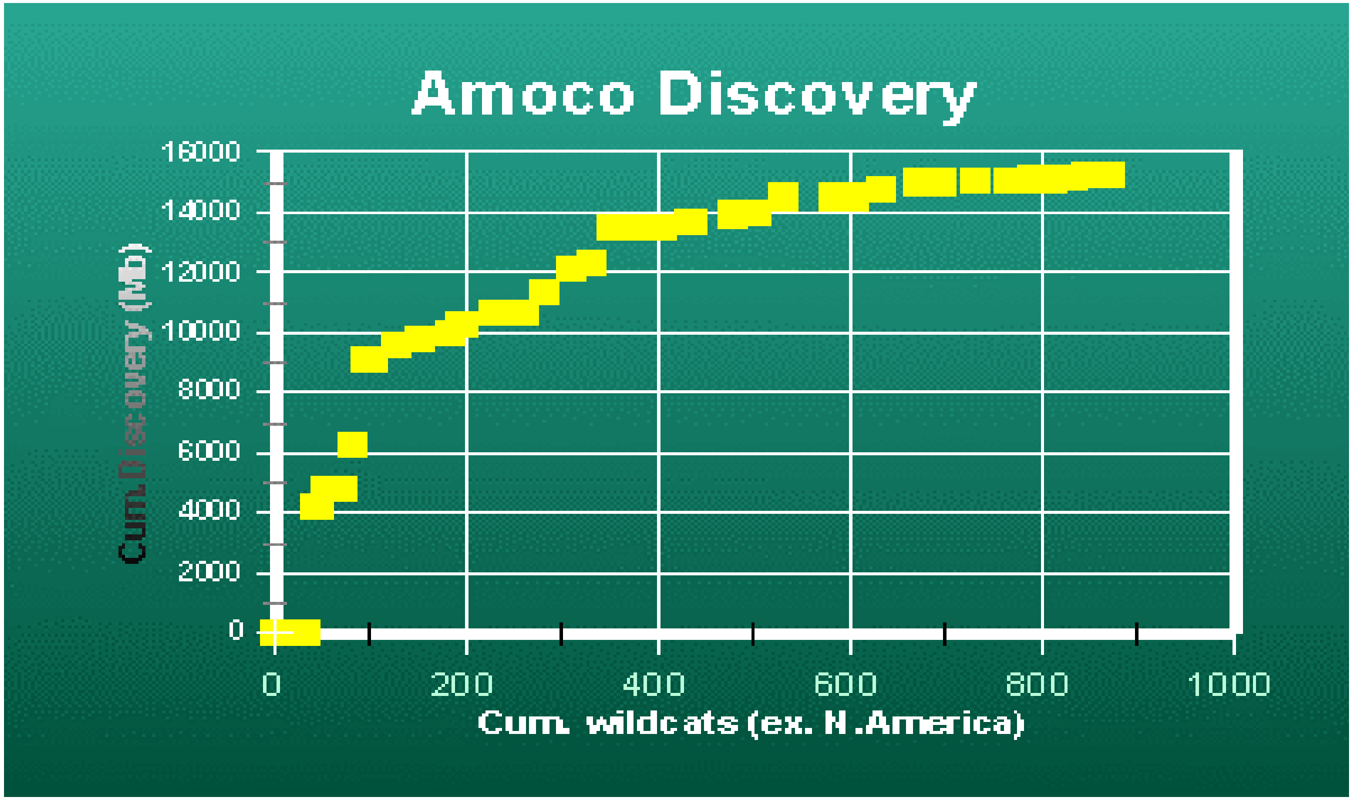
Source, 1975-2002 data National Energy Board, CDA
1960-1974 data US-DoE-Energy Information Administration

Forecast - LBST, (for Alberta: EUB Alberta)

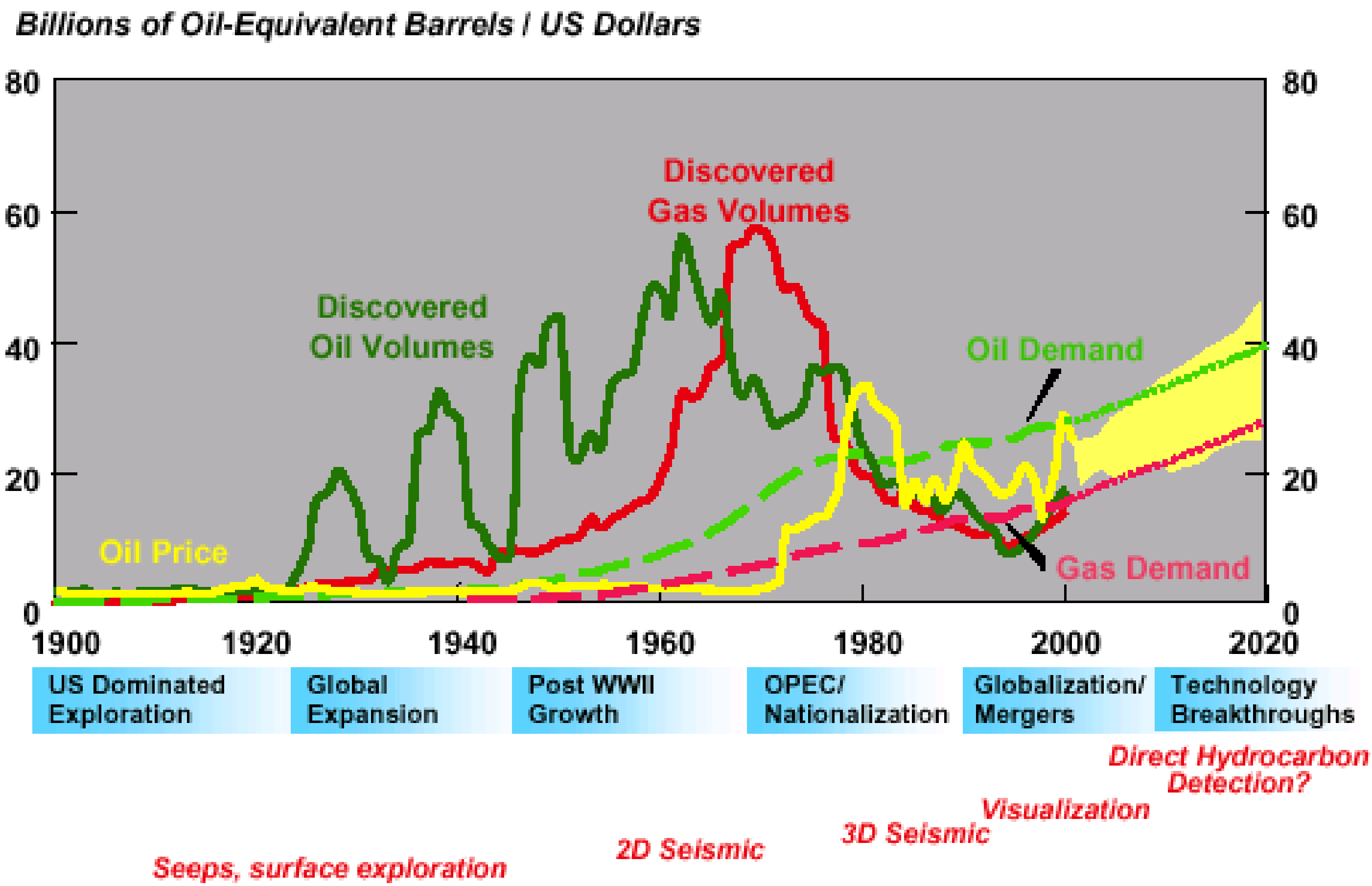
Oil Production in Canada (including tar sands)



Oil Production in Saudi Arabia



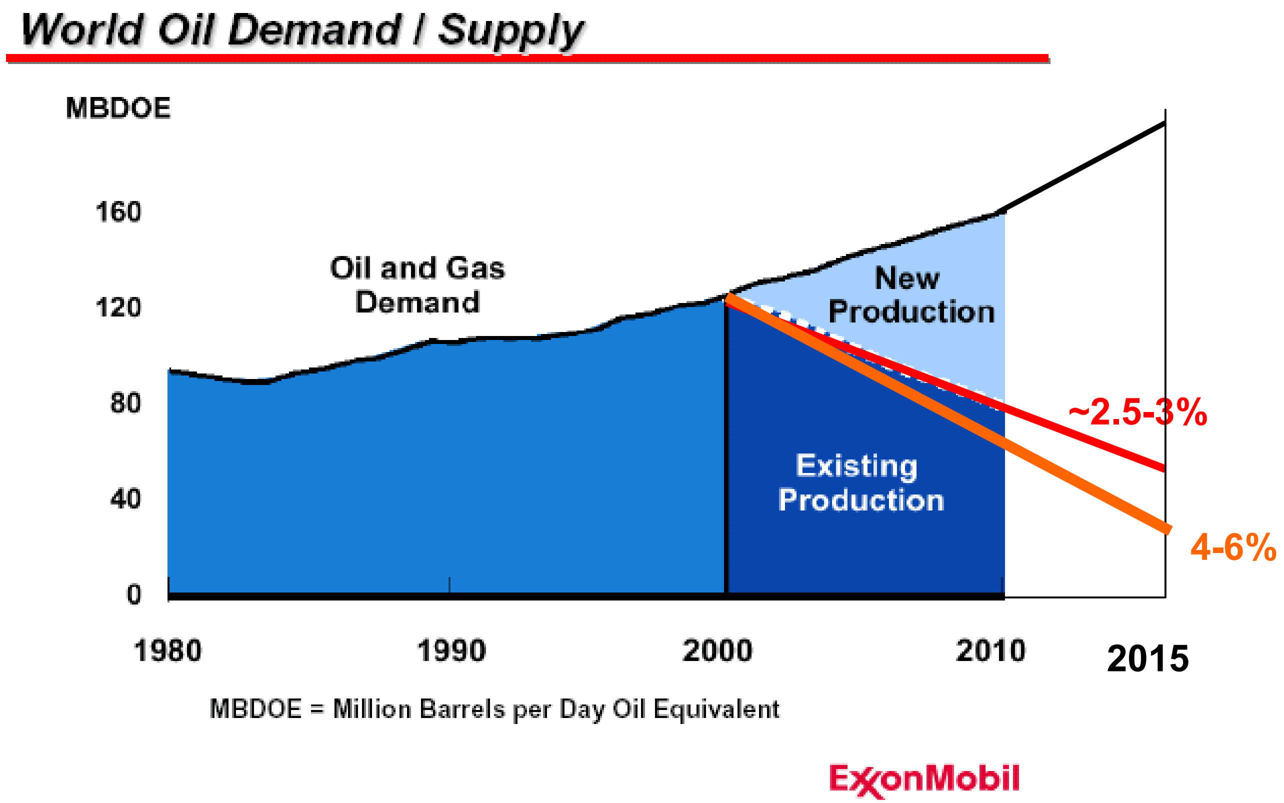
AMOCO could not increase discovery, although there were a lot of exploration wells



Source EXXON (2003)

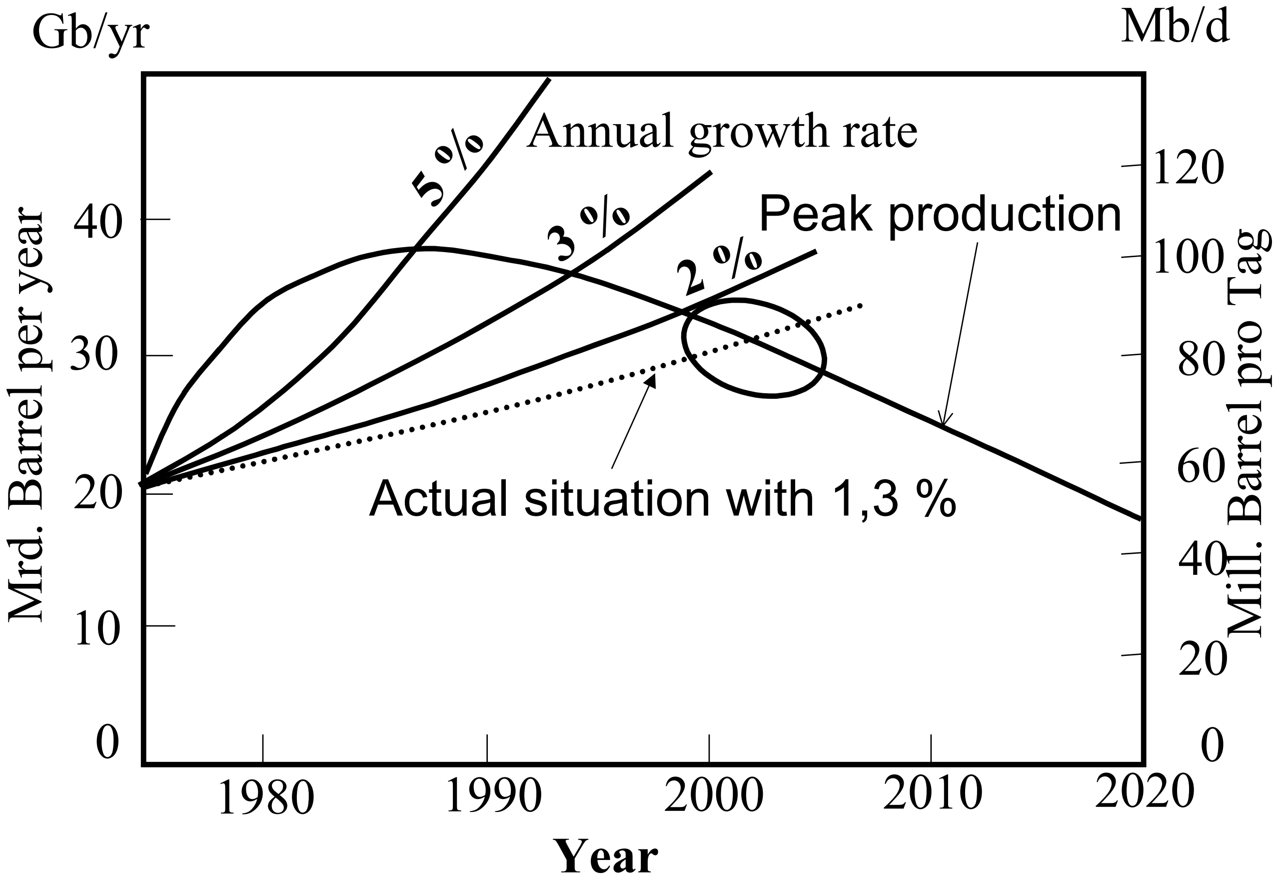
*"We estimate that world oil and gas production from existing fields is **declining at an average rate of about 4 to 6 percent a year**. To meet projected demand in 2015, the industry will have to add about 100 million oil-equivalent barrels a day of new production. **That's equal to about 80 percent of today's production level. In other words, by 2015,** we will need to find, develop and produce a volume of new oil and gas that is equal to eight out of every 10 barrels being produced today. "*

Jon Thompson
President of Exxon Mobil Exploration Company, Oct 2003



Required investments to add new production to satisfy projected demand

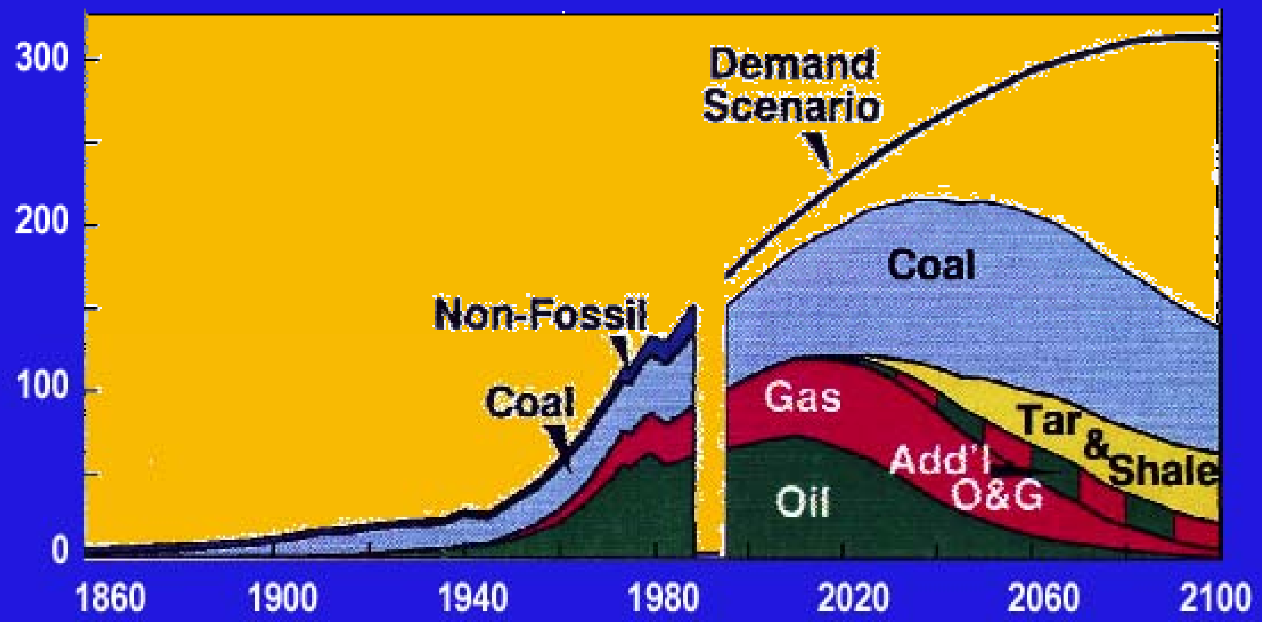
- 1,500 billion through 2015 (EXXON estimate)
- 4,000 – 6,000 billion through 2014 (Matt Simmons estimate)



“Global 2000“, published in 1980

World Energy

Millions of Barrels per Day (Oil Equivalent)



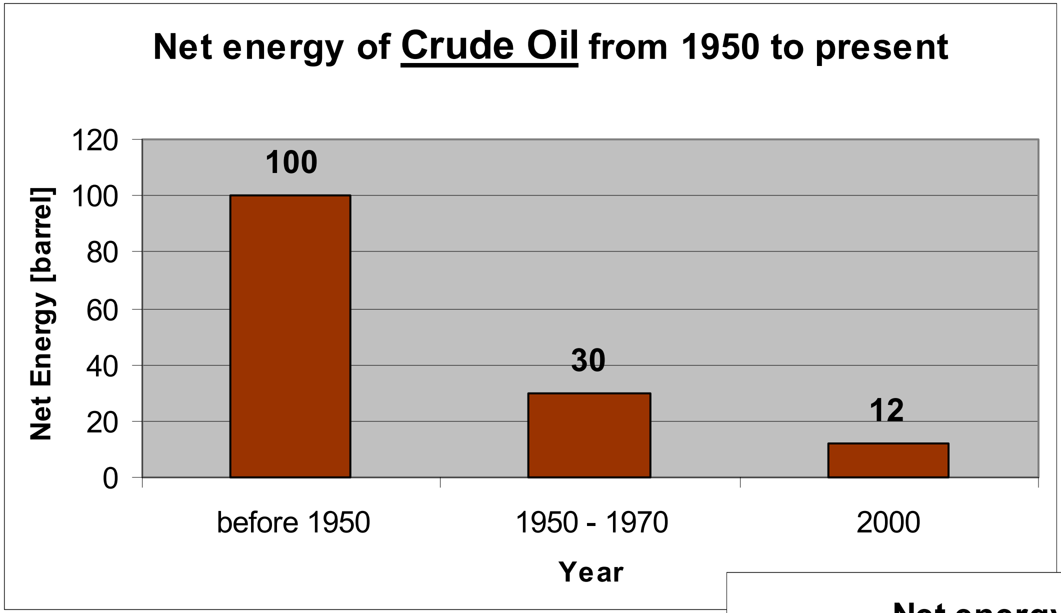
Source: John F. Bookout (President of Shell USA) ,"Two Centuries of Fossil Fuel Energy" International Geological Congress, Washington DC; July 10,1985. Episodes, vol 12, 257-262 (1989).

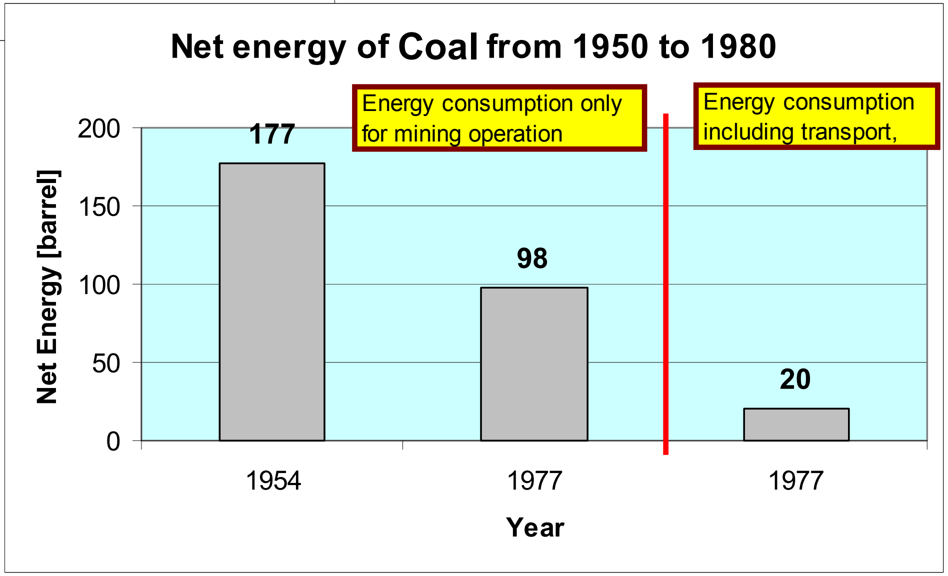
“Energy Density”

Wood < Coal < Oil < Natural Gas

“Net Energy”

Net Energy = Energy produced – Energy used for production


Net energy of Crude Oil from 1950 to present
Net Energy [barrel]
120
100
80
60
40
20
0
100
30
12
before 1950
1950 - 1970
2000
Year


Net energy of Coal from 1950 to 1980
Energy consumption only for mining operation
Energy consumption including transport,
Net Energy [barrel]
200
150
100
50
0
177
98
20
1954
1977
1977
Year

"When I get new information, I change my conclusions. What do you do, Sir?" , Meynard Keynes

Consequence

- Oil (and Energy) will not run out but availability will decrease
- ***Cheap energy*** might be "running out"
- "Smart Energy Use" will be more important than today
- Must change perception to use of energy and resources and exploit energy saving technology and processes
- Become more attuned to work with low-density energy

" .. We do opt to go to the moon not because it is easy .. but because it is hard …" JFK, 1962

Part 2 of Presentation :

Radiant Cooling and Dedicated Outdoor Air Systems (DOAS): Presentation of innovative and proven technologies and approaches, in order to lower energy use and improve comfort level in air-conditioning

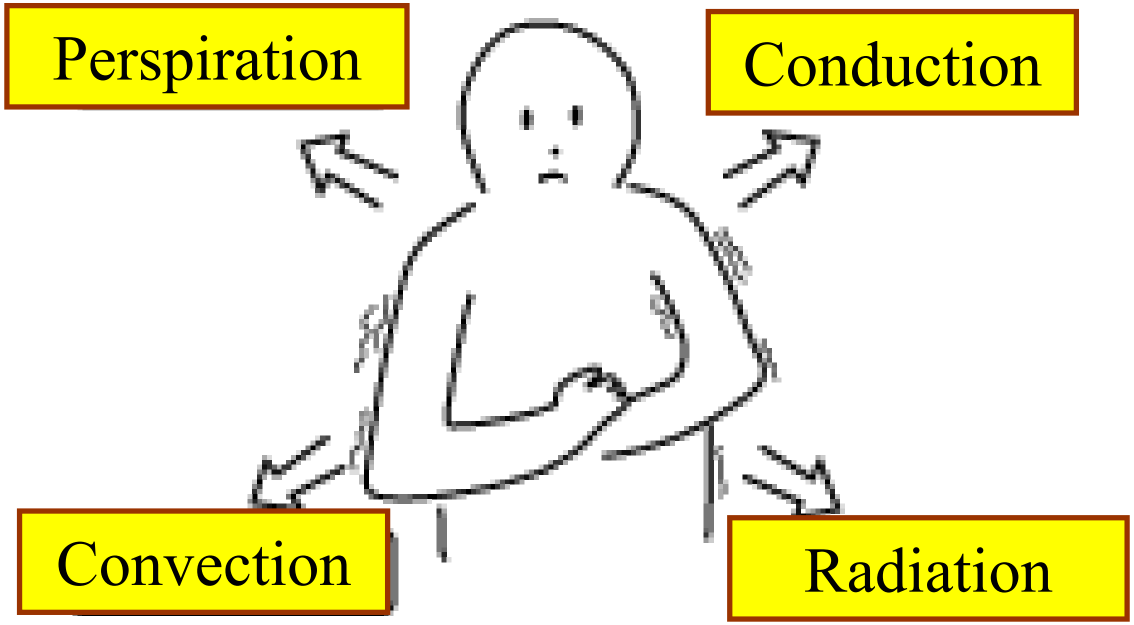
This part of the presentation introduces the concepts and technologies about healthier and more energy efficient air-conditioning technology; Radiant cooling and DOAS.

These technologies are being adopted more and more by the HVAC industry in the US, because of the obvious advantages. These systems are developed to an advanced state and are widely used in Europe. Hawaii can benefit in particular, if the cold deep seawater is used as a natural heat, allowing high energy savings between 70-85 %

Issues discussed in presentation:

- Heat transfer mechanisms in human bodies with cooling
- Radiant cooling
- Dedicated Outdoor Air Systems
- Case studies
- Seawater Air-Conditioning

Main Mechanisms of Heat Transfer from Human Body



Target Cooling rate = 90 watts

Perspiration

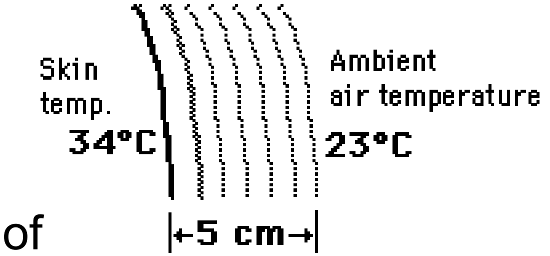
Cooling mechanism = Evaporation of perspiration from the skin and the evaporative cooling from exhaled moisture

Q/t max = 17 watts

Conduction

Convection

$$\frac{Q}{t} = \frac{kA(T_{hot} - T_{cold})}{d}$$



k the thermal conductivity of

A typical body area

d “wall thickness” (2 inch = 5 cm)

Q/t max = 10.5 watts

Radiation

$$\frac{Q}{t} = e\sigma A(T_{hot}^4 - T_{cold}^4)$$

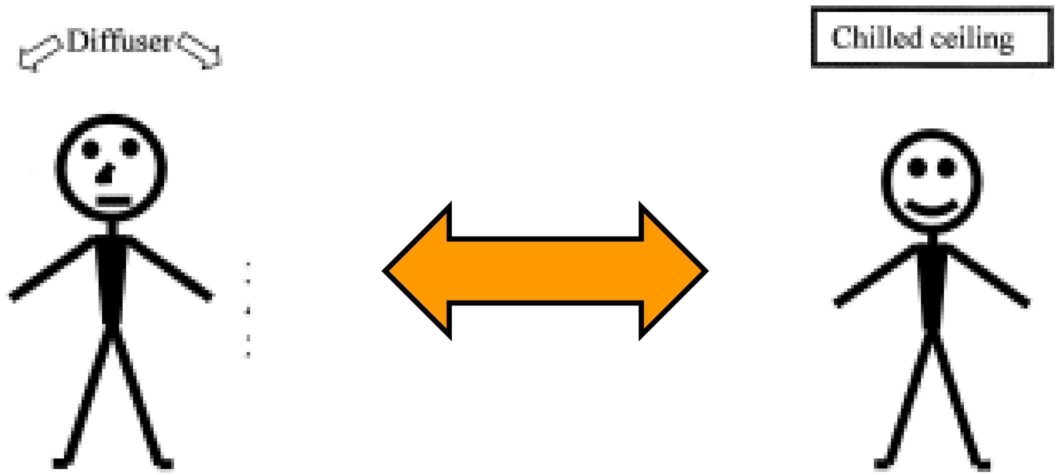
σ Stefan-Boltzmann constant

Emissivity ; e=1 perfect radiatitor, **e=0.97** human skin

Q/t max = 133 watts

Conventional All-Air System

Radiant Cooling



Radiation	30%
Convection	40%
Perspiration	30%

Radiation	50%
Convection	30%
Perspiration	20%

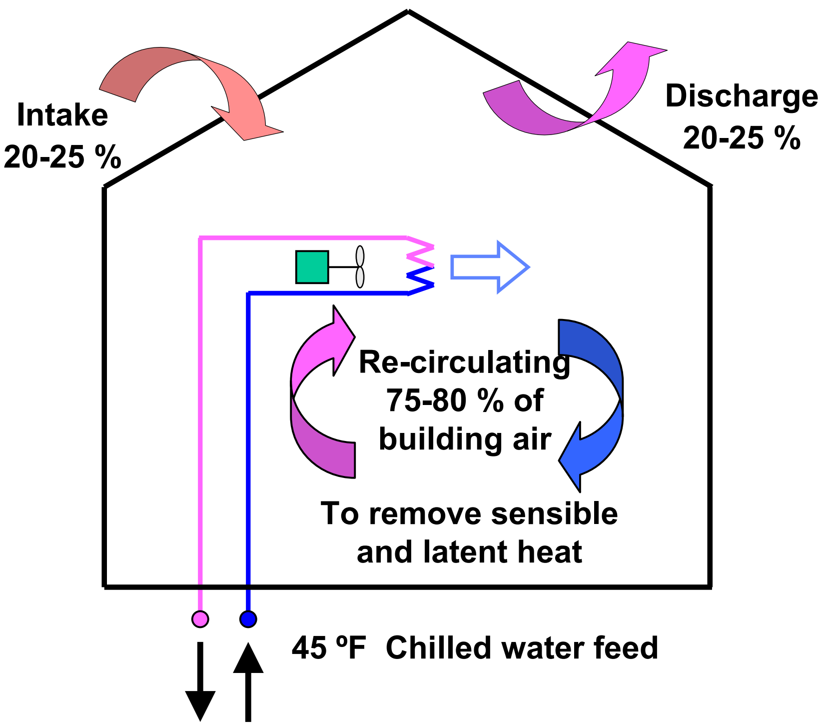
Other Advantages of Heat Transfer from Human Body associated with radiant ceiling panels:

- Human perceives lower room temperature:
  Actual temperature (dry bulb) 78°F, same temperature perceived as 75°F with radiant ceiling cooling
  - Results in savings in reduction on cooling loads and higher efficiency
- Less perspiration and no draft felt
- Human head (which emits much of the heat) can emit more heat with radiant ceilings (cold head and warm feet)

Comparison of cooling approaches:

Conventional "All-air cooling

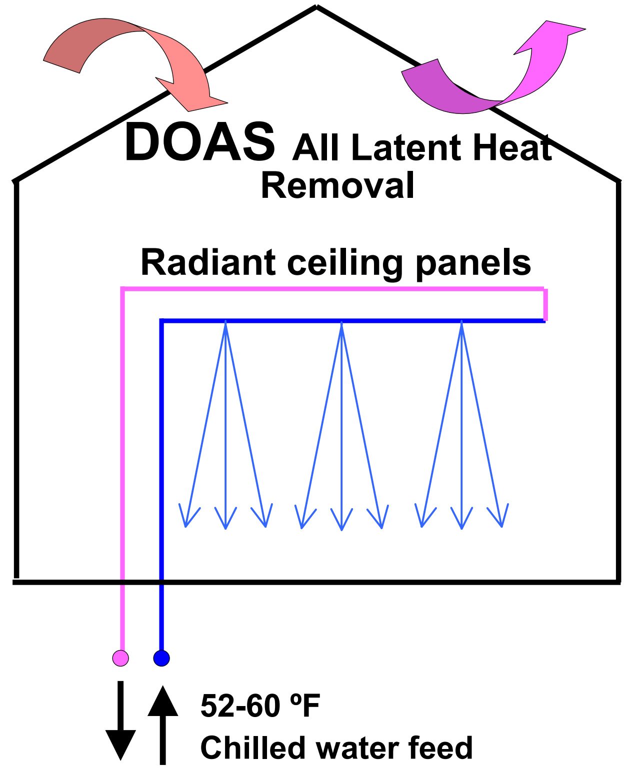
Make-up air = 20-25 % of building air



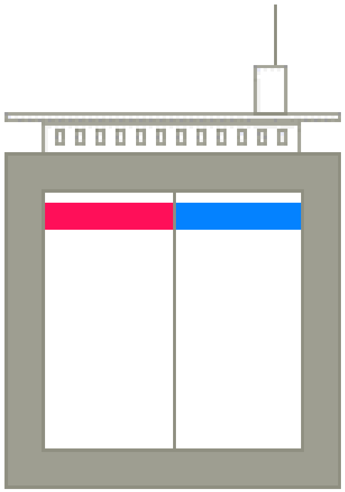
Cooling through mainly convection
circulated air removes sensible and latent heat from building

Radiant cooling

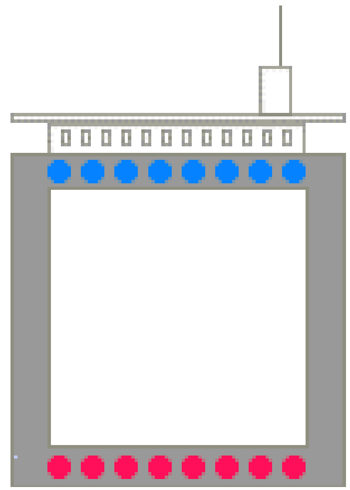
Ventilation according to standrads
about 30 – 70% less than in All-Air



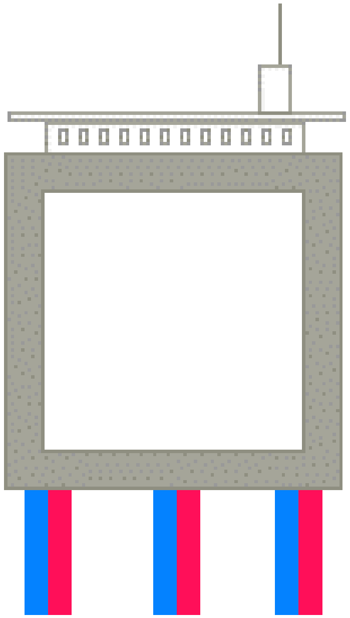
Cooling through radiation and convection
Cool surfaces remove sensible heat;
Dehumidification units remove latent heat



Radiant cooling

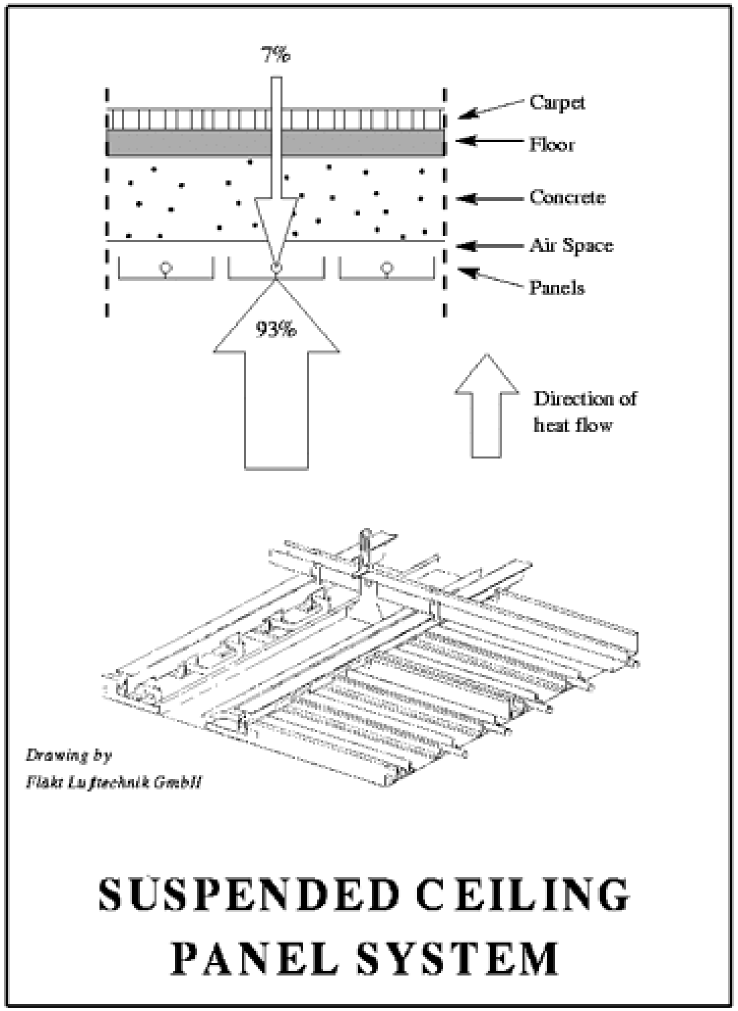


Concrete core cooling



Using natural heat sinks

Types of radiant cooling systems



Radiant Heating & Cooling

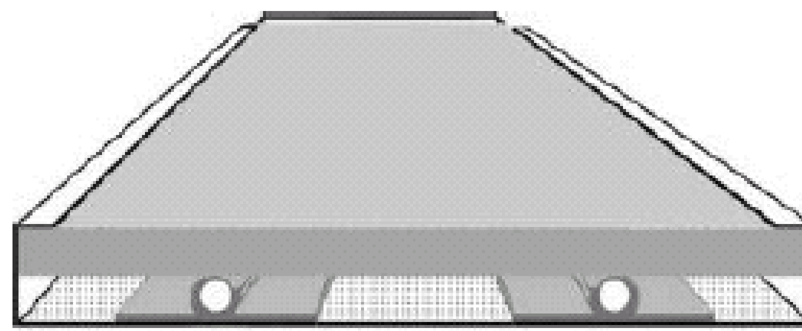
Radiant cooled ceiling with integrated air diffusers

Radiant cooled ceiling in an open office area

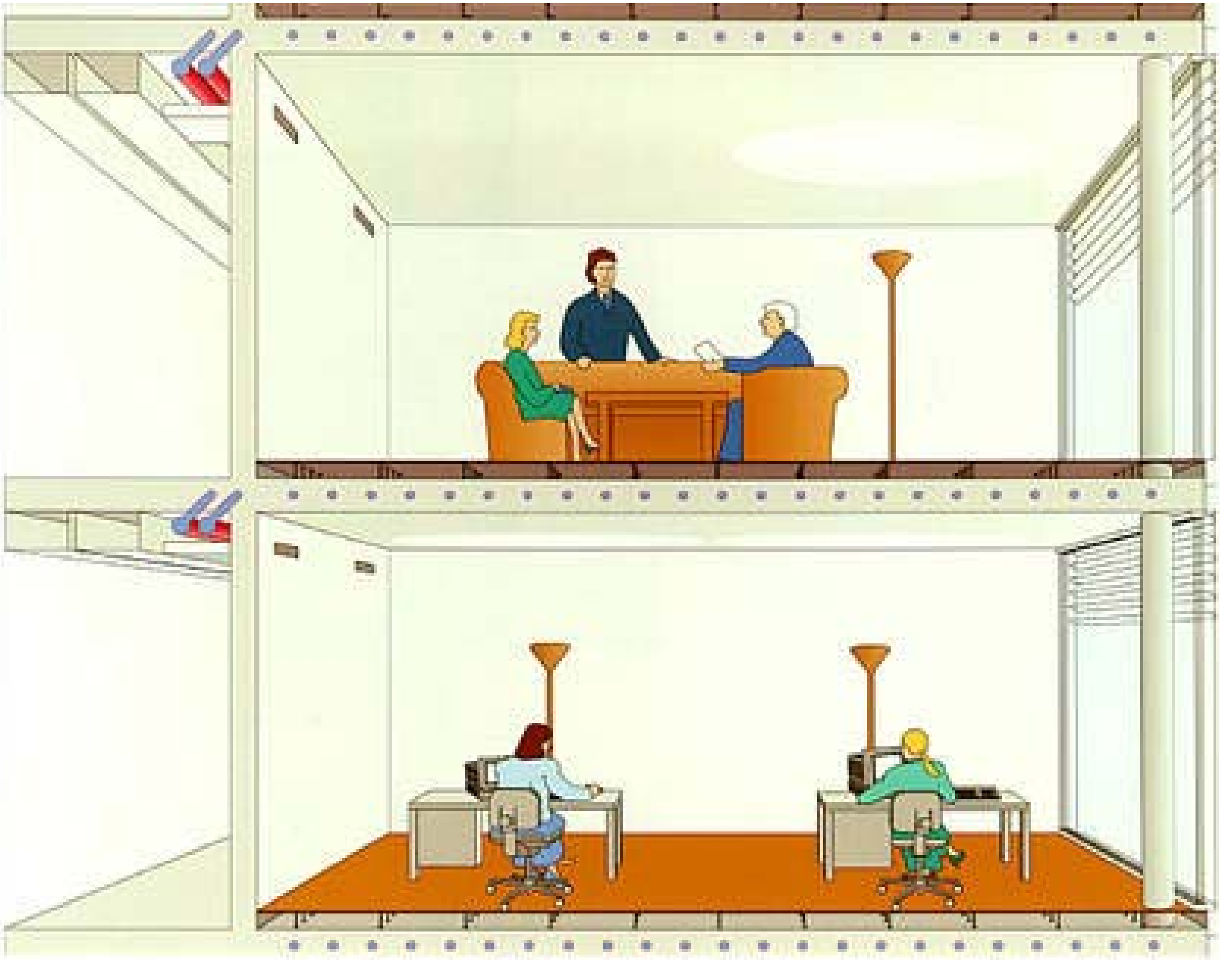
Providing unlimited architectural freedom

Embedded in concrete beams

(a) Free hanging panel design for enhanced upper surface HT



(b) "Drop in" panel with back insulation



Concrete core cooling

What is DOAS:

"Dedicated Outdoor Air Systems"

Main Differentiators:

1. The delivery of ventilation air must be separated from the space conditioning systems for proper ventilation air distribution..
2. Conditioning the outdoor air (OA) to handle all of the space latent load and much of the space sensible load employing energy recovery
3. Meet the balance of the space sensible loads with a parallel system.

Key Benefits of DOAS/Radiant Cooling System with Total Energy Recovery:

- **High energy savings due to lower air flow** (about 30 to 50 % energy savings in comparison to conventional All-Air Systems)
- Use **more effective hydronic heat transfer** than conventional All-Air Systems
- **Superior IAQ and better comfort levels** (no draft, uses superior heat transfer mechanism of human body)
- **Lower equipment and operating costs** (lower air supply volumes, smaller chillers, better energy recovery)
- **No air is circulated inside the building** (building-wide contamination from localized release is avoided, no sick-building syndromes)

(Cont.) Key Benefits of DOAS/Radiant Cooling System

Biological contaminant generation inside the buildings minimized or eliminated (no septic contamination in AC-ducts since wet surface cooling coils are eliminated, **DOAS/Radiant cooling is ideal for medical & public health buildings**)

- **Outside air-treatment far superior** (application of superior filters and other advanced is much more effective and cheaper, better protection to intentional release of air-borne agents)
- **Cooling ceilings panels can use sprinkler system in buildings**
- **Compact design needs less space in buildings** (Rule of thumb: Accommodate 20% more floors in buildings since plenum space is reduced)

DOE Report (1999) Energy Savings Potential in HVAC

Table 4-1: Energy Savings Potential Summary for 15 Options

Technology Option	Technology Status	Technical Energy Savings Potential (quads)
Adaptive/Fuzzy Logic Controls	#3	0.23
Dedicated Outdoor Air Systems	Current	0.45
Displacement Ventilation	Current	0.20
Electronically Commutated Permanent Magnet Motors	#2 ent	0.15
Enthalpy/Energy Recovery Heat Exchangers for Ventilation	ent	0.55
Heat Pumps for Cold Climates (Zero-Degree Heat Pump)	Advanced	0.1
Improved Duct Sealing	Current/New	0.23
Liquid Desiccant Air Conditioners	Advanced	0.2 / 0.06[12]
Microenvironments / Occupancy-Based Control	Current	0.07
Microchannel Heat Exchanger	New	0.11
Novel Cool Storage	#1 rrent	0.2 / 0.03[13]
Radiant Ceiling Cooling / Chilled Beam	Current	0.6
Smaller Centrifugal Compressors	Advanced	0.15
System/Component Diagnostics	New	0.45
Variable Refrigerant Volume/Flow	Current	0.3

DOE Report (1999) Energy Savings Potential

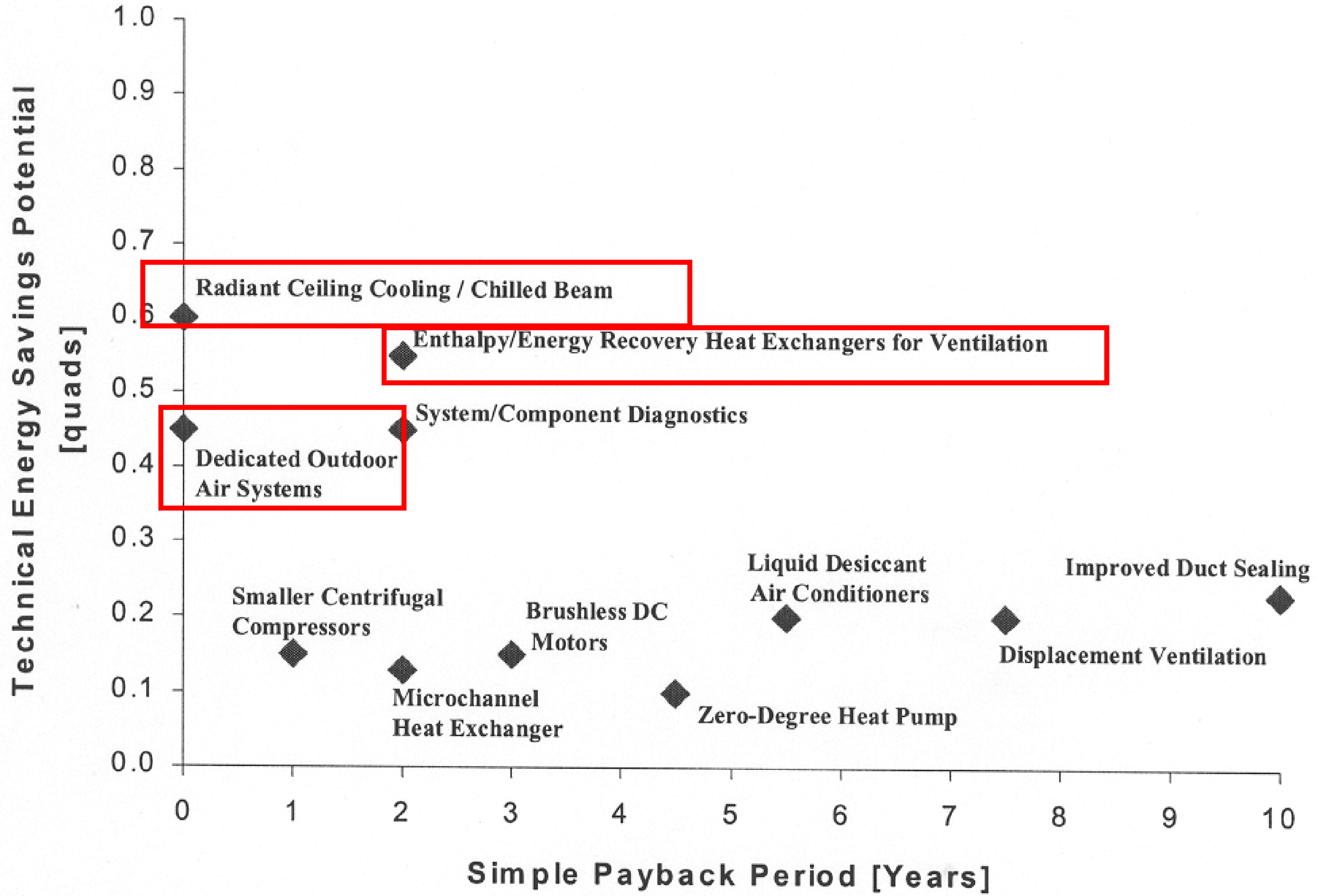


Figure 5-2: Estimated Technical Energy Savings Potential and Simple Payback Periods for the 15 Options

Table 4-6: Summary of Dedicated Outdoor Air Systems Characteristics

Characteristic	Result	Comments
Technical Maturity	Current	
Systems Impacted by Technology	All HVAC equipment	Heating, cooling, and ventilation systems
Readily Retrofit into Existing Equipment/Buildings?	Depends	A DOAS needs many more duct connections
Relevant Primary Energy Consumption (quads)	4.0 quads	All non-individual cooling and ventilation systems; OA heating energy
Technical Energy Savings Potential (quads)	0.4 to 0.5 quads	• 10% reduction in heating • 17% reduction in cooling • Approximately no net impact on ventilation energy
Approximate Simple Payback Period	Potentially immediate	Potentially lower first cost (in new construction and major renovation); includes benefit of additional rentable space
Non-Energy Benefits	Improved humidity control and occupant comfort	By delivering more appropriate space conditioning to different zones, zonal control decreases temperature swings, improving occupant comfort and possibly increasing productivity. In applications with small indoor humidity loads and low infiltration, a DOAS allows de-coupling of the latent and sensible load management by managing the OA (primary) humidity source separately.
Notable Developers/Manufacturers of Technology	Several	Penn State University, EPRI, McClure Engineering
Peak Demand Reduction	Yes	Yes, by ensuring only that occupied areas receive space conditioning during peak demand periods; a DOAS further reduces peak demand by decreasing OA cooling loads, which approach maximum values during peak demand periods.
Most Promising Applications	Buildings with large amounts of variably occupied space, such as office buildings, hospitals or schools. DOAS systems provide larger benefits in regions where the OA conditioning burden is larger.	
Technology "Next Steps"	Demonstration of energy saving and superior humidity control, design software.	

DOAS Characteristics and benefits ;

Source S.A. Mumma

Table 4-37: Summary of Radiant Ceiling Cooling Characteristics

Characteristic	Result	Comments
Technical Maturity	Current	Much more common in Europe than in the U.S.
Systems Impacted by Technology	All HVAC systems	
Readily Retrofit into Existing Equipment/Buildings?	No	Requires installation of large ceiling panels and piping throughout building.
Relevant Primary Energy Consumption (quads)	3.4 Quads	All non-individual cooling and ventilation energy, heating energy tied to OA
Technical Energy Savings Potential (quads)	0.6 Quads[64]	• 17% cooling energy reduction • 10% heating energy reduction (all from DOAS) • 25% ventilation energy reduction
Approximate Simple Payback Period	Potentially immediate	In new construction or major renovation
Non-Energy Benefits	Improved occupant comfort, low noise, low maintenance	Radiant heating/cooling generally considered more comfortable than forced-air methods. Low maintenance (assuming humidity issue properly managed). Less noise from air distribution. According to Stetiu (1997), radiant cooling reduces ventilation, which reduces space needed for ducts by up to 75%. Zoning readily implemented.
Notable Developers/Manufacturers of Technology	Frenger (Germany). Trox (Germany). Dadanco (Australia; Active Chilled Beams; uses smaller fans to distribute primary air through unit, in combination with secondary, room air)	
Peak Demand Reduction	Yes	Decreases the peak ventilation load required to deliver peak cooling. Stetiu (1997) found 27% demand reduction on average (throughout U.S.).
Most Promising Applications	Tight buildings with high sensible cooling loads, located in low-humidity cooling climates (e.g., hospitals due to one-pass ventilation requirement). Not buildings with appreciable internal moisture loads (e.g., health/fitness clubs, pools).	
Technology "Next Steps"	HVAC system designer/installer education with approach; integration into commonly-used HVAC design tools; demonstration of operational benefits. Cost comparison with VAV system using an enthalpy wheel and dedicated outdoor air systems. Energy savings of chilled beam versus VAV.	

DOAS Characteristics and benefits ;

Source S.A. Mumma

Main Concerns of Radiant Cooling (Chilled Ceilings) in parallel with DOAS:

- ❑ Condensation
- ❑ Capacity
- ❑ Costs

Condensation:

- Radiant cooling cannot be considered without unless there is parallel system to decouple sensible and latent loads
- DOAS must be able to remove all latent heat
- Exhaust Air Energy Recovery for total energy recovery in DOAS; “Enthalpy Wheel” exchanges humidity and heat between supply and exhaust air
- total energy recovery reduces the OA load on the cooling coil by 75 – 80 %
- Radiant panels only for the sensible heat removal. Panel should not be below room DPT.
- Condensation does not occur instantaneously; needs time in transient mode

Condensation can and must be avoided by good controls

Capacity:

- Radiant cooling is taking the total or partial sensible load
- Balance of the design chillers load comes from DOAS, parallel to the radiant ceiling
- Rule 95-126 W /m^2 of total heat has to be removed; max. removal by “drop-in” radiant panel 95 W /m^2
- DOAS removes all the outside air (OA) load and the space latent load
- DOAS might also remove about 10-15 % of the sensible load in space
- Sensible load remaining for radiant panels is about 45 W/m^2 (or about 50% of ceiling factor). Some building (with large of glazed walls) require additional panel area

No capacity problem when radiant cooing has parallel DOAS; preferably with Total Energy Recovery

Costs:

- Improved indoor air quality has already economical benefit
- 58 billion $ per year from sick-building sickness; Possible 200 billion per year $ in gain in productivity (Lawrence Berkeley Lab)
- Smaller chillers and pump sizes smaller due to reduced air flow
- VAV-Ductwork greatly reduced or eliminated
- Plenum depth reduced (more useable/rentable space available)
- Use fire suppression piping for delivery of chilled water (ASHRAE approved)
- Smaller electrical and mechanical systems
- Significant less energy use and lower operation costs
- Simple installation and repair
- <u>But: More costs for ceiling panels.</u>

Net savings about$2 / ft^2

Example of Radiant/DOAS Project

Loaction: Düsseldorf/Germany *"Düsseldorfer Stadttor"*

Floor plan

mie gilt, nämlich die Firma NEK aus Zürich. Würde man hier nicht höchstes Know-how investieren, könnte es passieren, daß ein ganzes Herzstück des Hauses sich als nichtfunktionsfähig erweist. Die Brunnen müssen etwa 600 000 m^3 Wasser pro Jahr spenden. Da die Untere Wasserbehörde aber keine ganzjährige Vorhersage für die Wassertemperatur abgeben mochte, verwies sie das ganze Verfahren an die Obere Wasserbehörde (Bezirksregierung). Diese genehmigte mit 900 000 m^3 eine bestimmte Reserveentnahme.

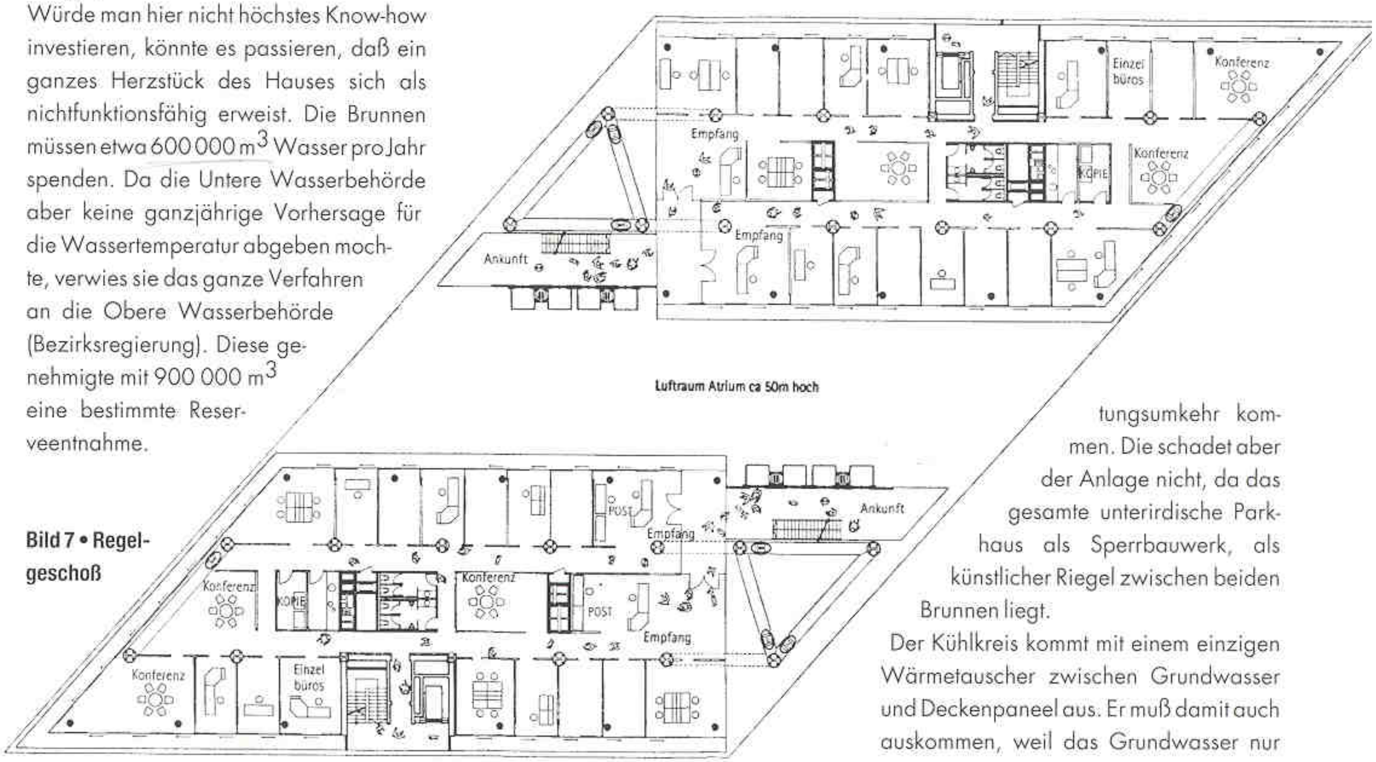
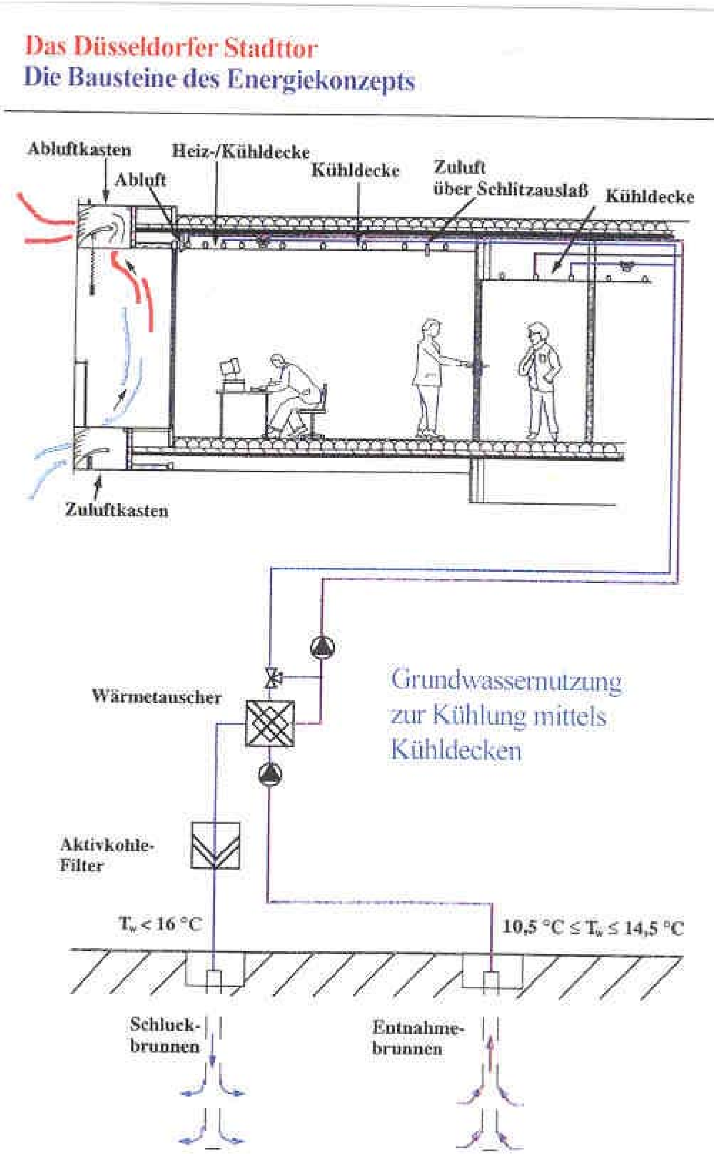


Bild 7 • Regelgeschoß

tungsumkehr kommen. Die schadet aber der Anlage nicht, da das gesamte unterirdische Parkhaus als Sperrbauwerk, als künstlicher Riegel zwischen beiden Brunnen liegt.

Der Kühlkreis kommt mit einem einzigen Wärmetauscher zwischen Grundwasser und Deckenpaneel aus. Er muß damit auch auskommen, weil das Grundwasser nur



Enclosed balconies with air exchange ducts

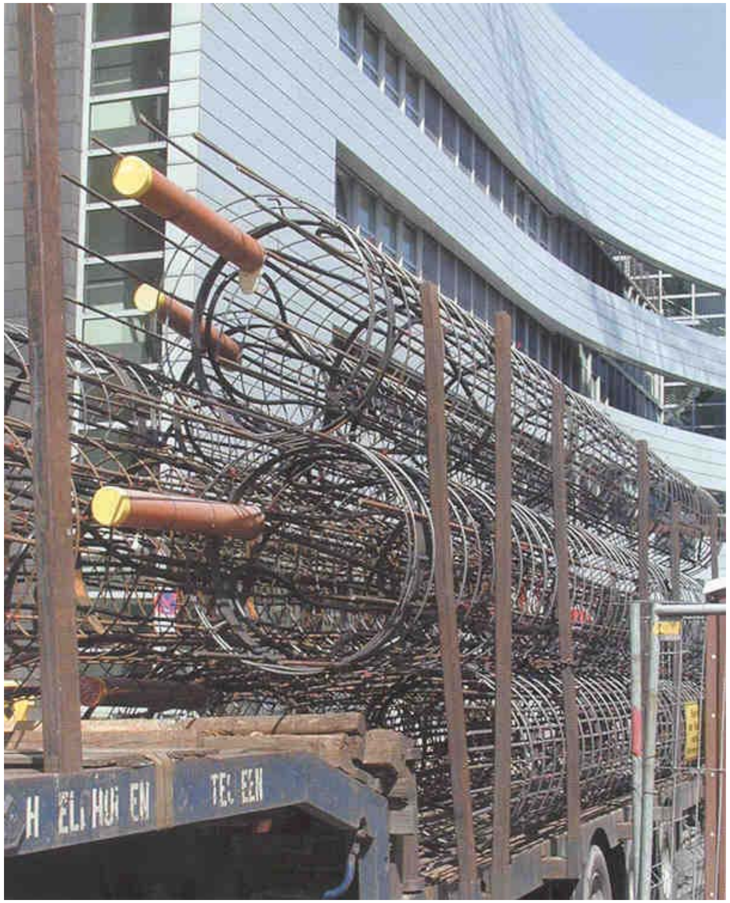
Enthalpy Wheel

Exchanges sensible and latent loads; potential energy savings up to 80% for outside air

Using this technology can handle the typical latent loads in Hawaii

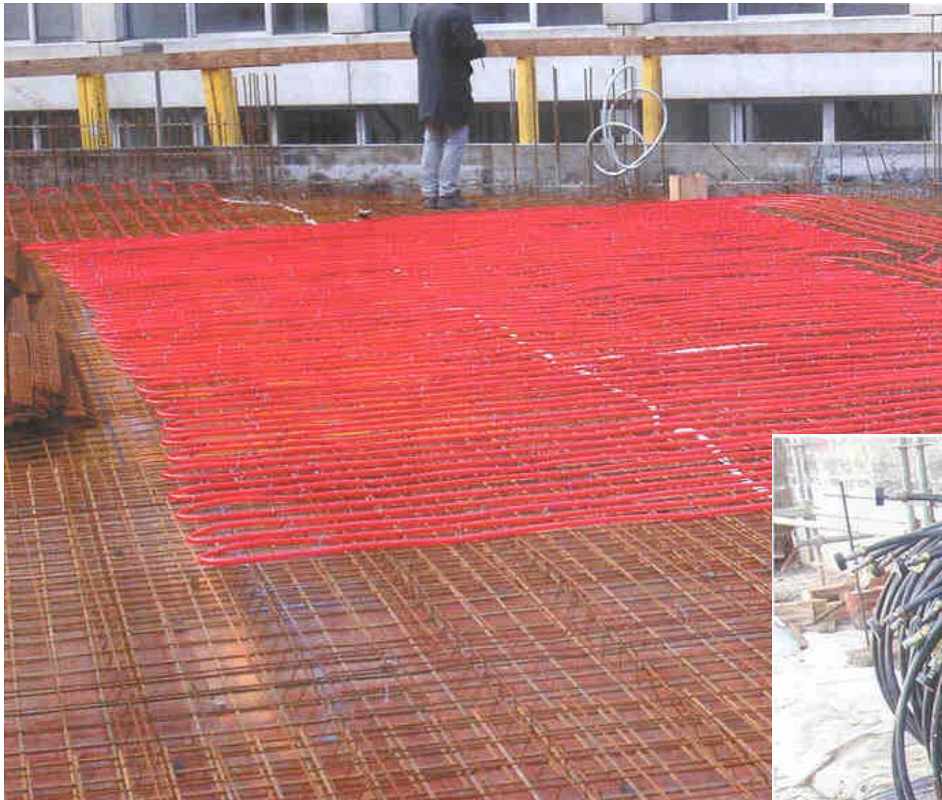
Example of Concrete Core Cooling

Location: Düsseldorf/Germany

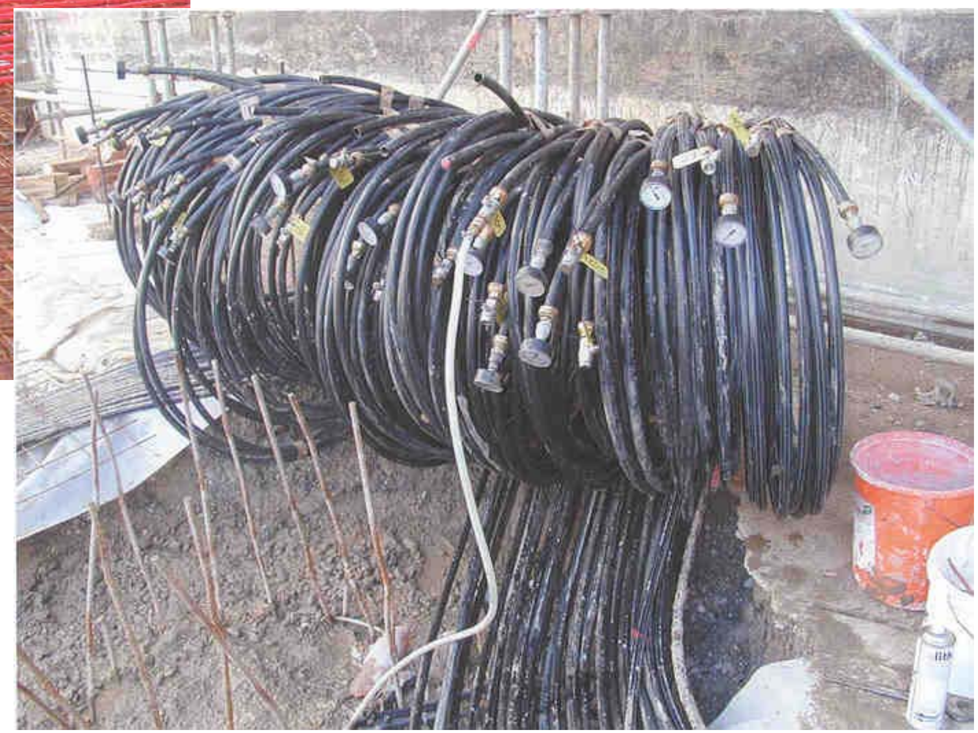


Piles with hydronic heat transfer coils .. No ground water is taken from the ground .. only heat exchange

Concrete slab with hydronic heat transfer coils

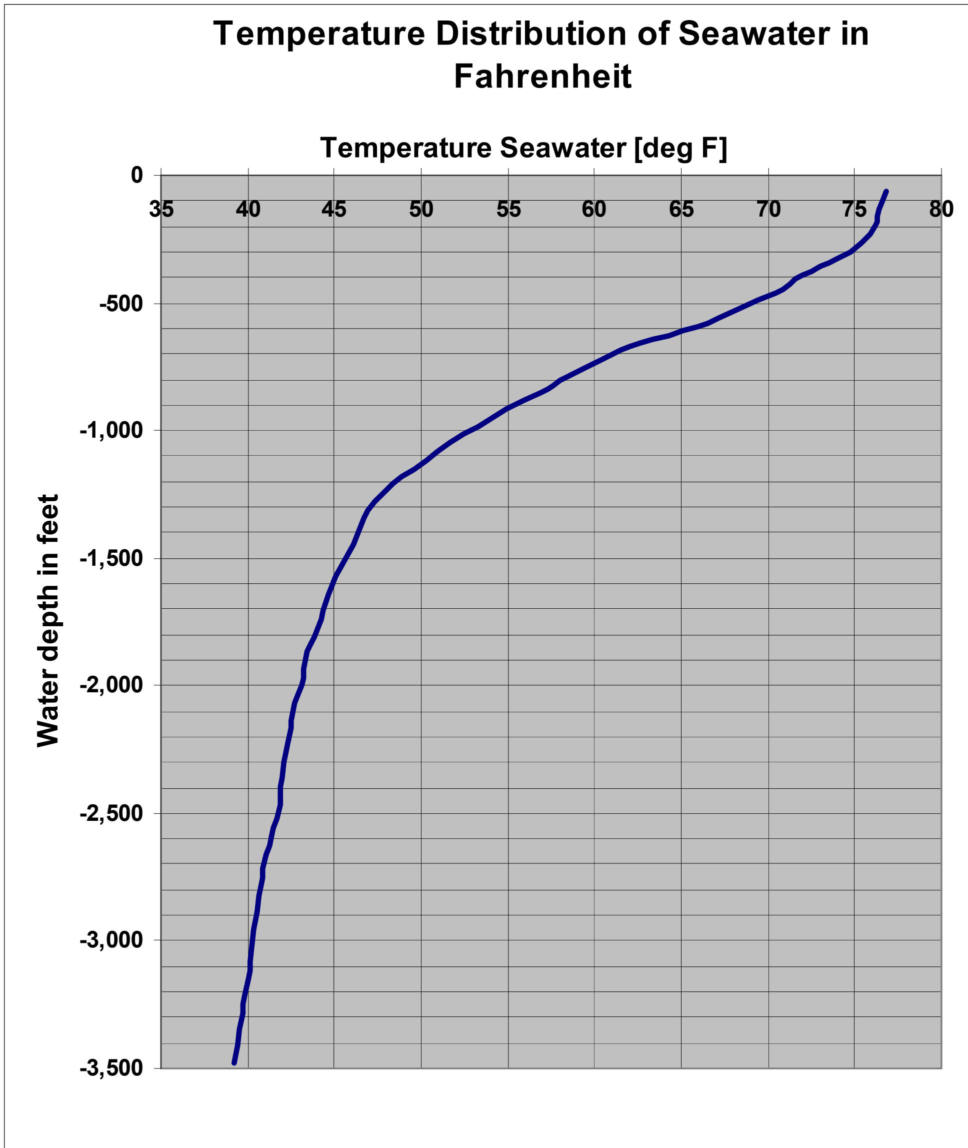


Concrete slab with hydronic heat transfer coils

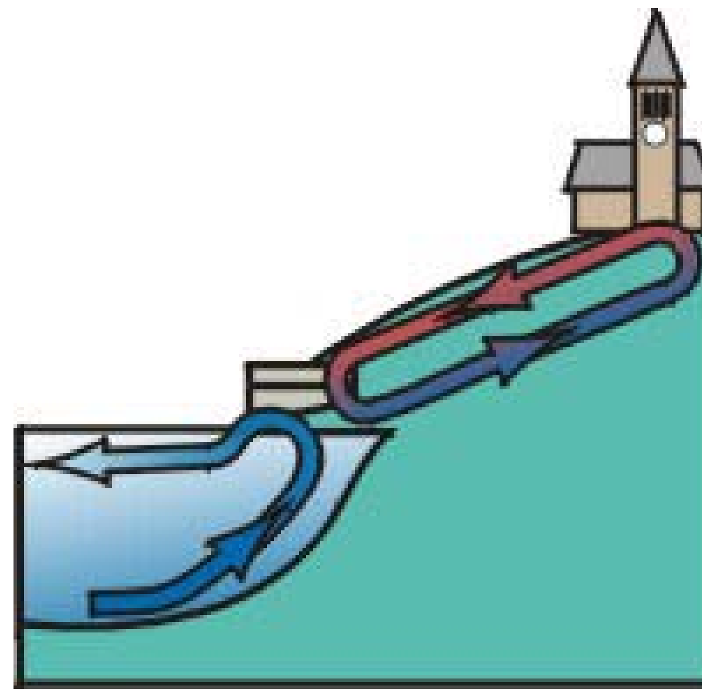


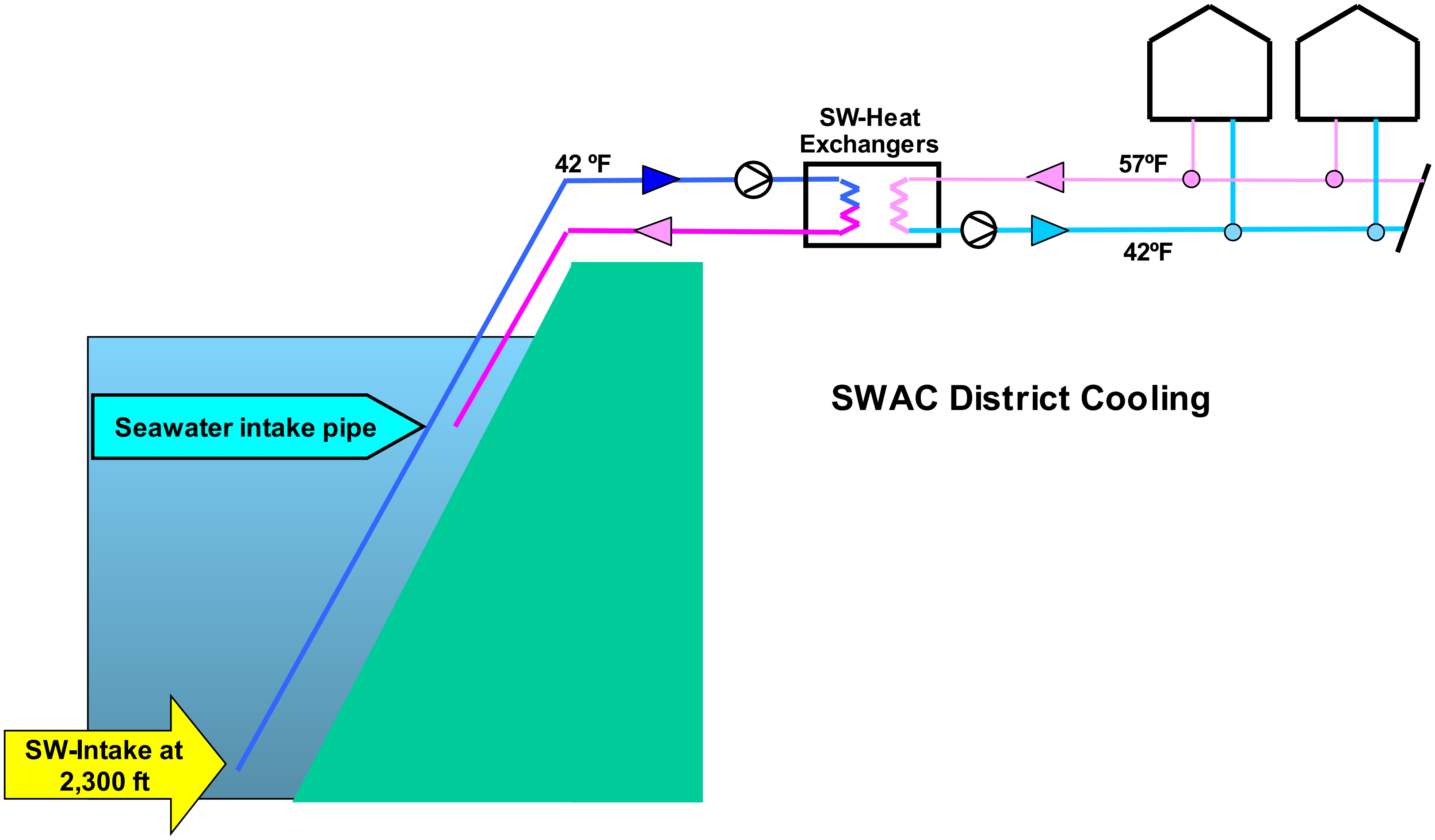
Terminals of heat transfer loops in piles

Principles of Seawater Air-Conditioning

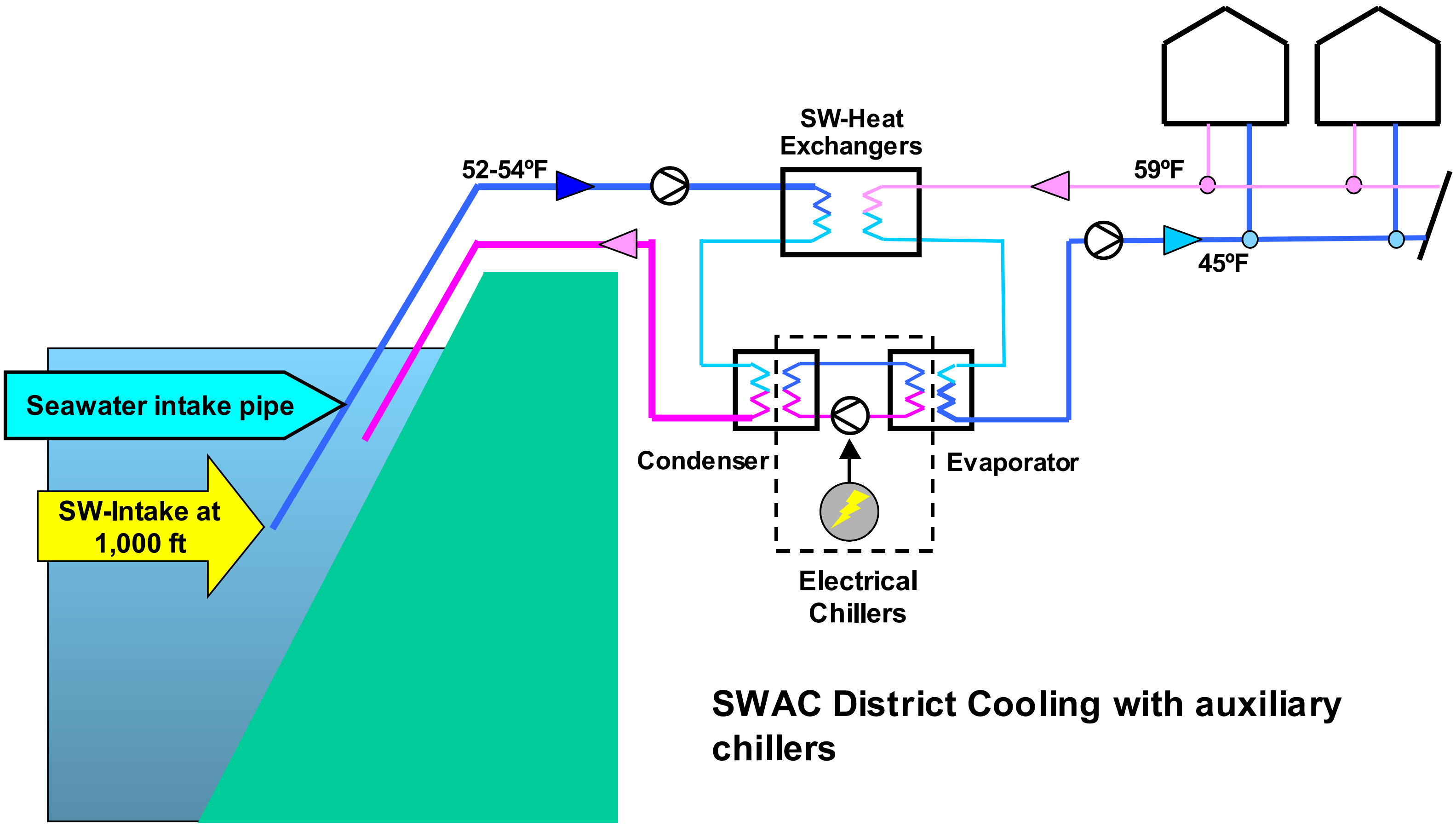


Using deep cold seawater as natural heat sink

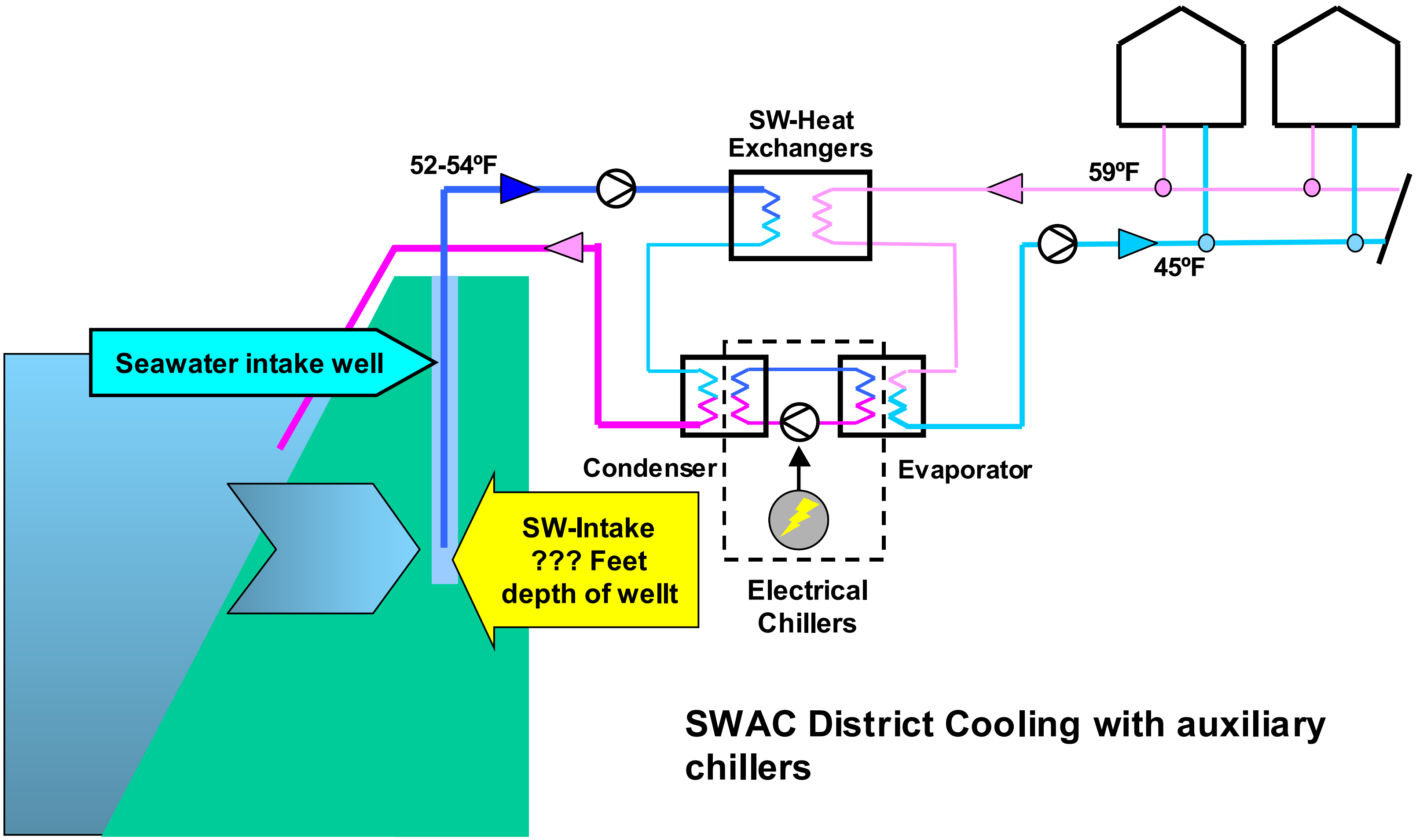




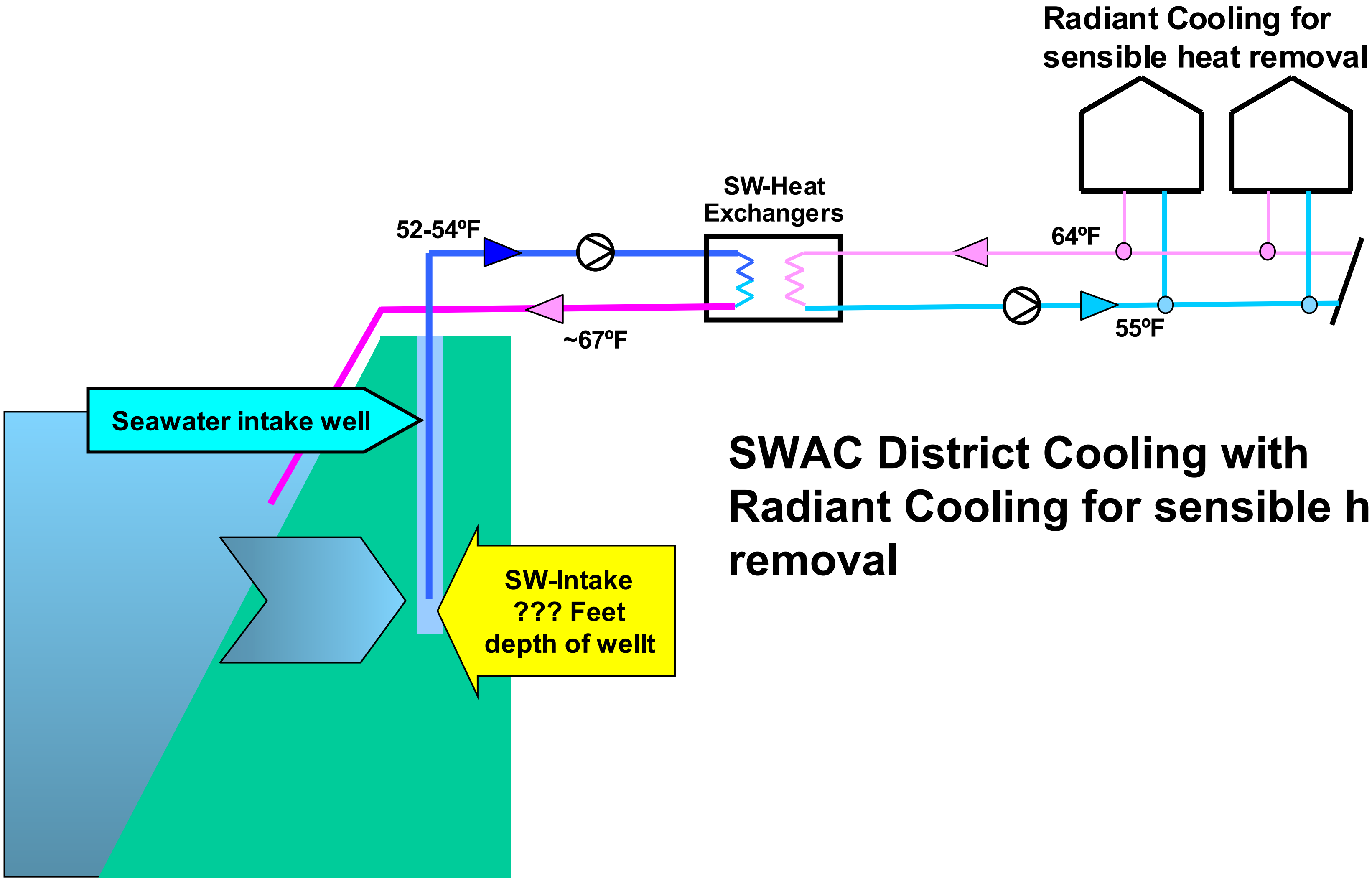
Cold seawater extracted from ocean through seawater pipeline (CWP)



Cold seawater extracted from ocean through seawater pipeline (CWP)



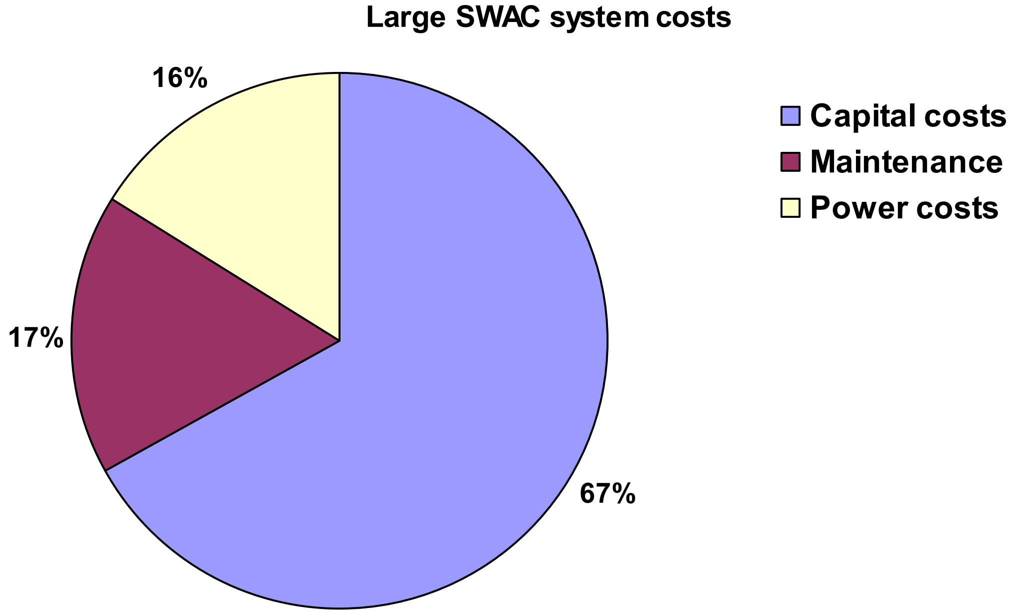
Cold seawater extracted from ocean through suction well (CWP)



SWAC District Cooling with Radiant Cooling for sensible heat removal

Large SWAC systems costs:

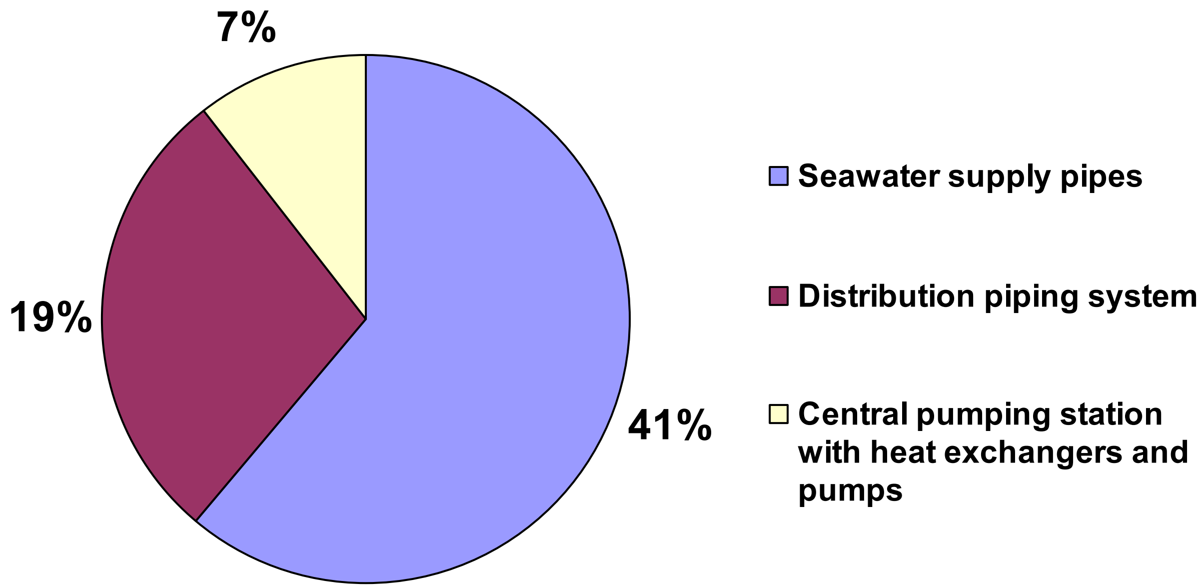
Capital costs	67%
Maintenance	17%
Power costs	16%
	100%



Capital costs of large SWAC system:

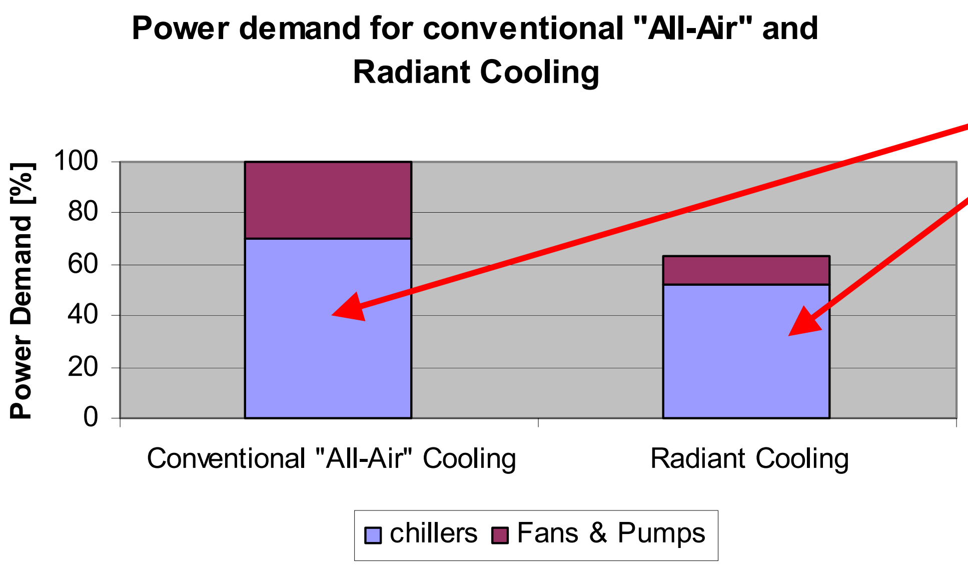
Seawater supply pipes	41%	Percentages of total SWAC costs
Distribution piping system	19%	
Central pumping station	7%	
	67%	

Capital costs of large SWAC system



Power demand for conventional "All-Air" and Radiant Cooling

	conventional "all-air" cooling	radiant cooling
Chillers	70	52
Fans and pumps	30	11
sum	100	63



Under SWAC scenario, power demand for chillers can be eliminated or reduced by cold seawater

This results in substantial costs saving

Integrated Innovative HVAC & SWAC: The Next Generation

DOAS/Radiant Cooling System Integrated with Seawater Air-Conditioning Results in Unparalleled HVAC Approach for the Hawaiian Islands … and beyond

Combining High-Energy Savings and Superior Indoor Air-Quality HVAC

Key Benefits of DOAS/Radiant Cooling System with Total Energy Recovery:

- High energy savings due to lower air flow (about 30 to 50 % energy savings in comparison to conventional All-Air Systems)
- Use more effective hydronic heat transfer than conventional All-Air Systems
- Superior IAQ and better comfort levels (no draft, uses superior heat transfer mechanism of human body)
- Lower equipment and operating costs (lower air supply volumes, smaller chillers, better energy recovery)
- No air is circulated inside the building (building-wide contamination from localized release is avoided, no sick-building syndromes)
- Biological contaminant generation inside the buildings minimized or eliminated (no septic contamination in AC-ducts since wet surface cooling coils are eliminated, **DOAS/Radiant cooling is ideal for medical & public health buildings**)
- Outside air-treatment far superior (application of superior filters and other advanced is much more effective and cheaper, better protection to intentional release of air-borne agents)
- Cooling ceilings panels can use sprinkler system in buildings
- Compact design needs less space in buildings (Rule of thumb: Accommodate 20% more floors in buildings since plenum space is reduced)

For more benefits go to next page ➔

Key benefit of Seawater Air-Conditioning (SWAC):

- Use the cold deep seawater as a natural heat sink can avoid up to 70% in energy for the HVAC cooling load.

Key Benefits of Integrated DOAS/Radiant System and SWAC :

- **Have all the benefits for superior IAQ from DOAS/Radiant Cooling system**
- **Higher energy efficiency** than SWAC working with conventional (All-Air) HVAC
- **Can operate at higher chilled water temperature**, therefore the seawater can have a higher temperature than SWAC systems with All-Air systems. (Required temperature of supply chilled water: ~42°F for conventional systems, ~55°F for radiant cooling)
- **Reduces or eliminates the need to chill the seawater from wells** which results in simpler **operation** and more cost-effective operation.

Abbreviations:

HVAC : Heating, Ventilation, Air-conditioning

DOAS : Dedicated Outside Air Systems

SWAC : Seawater Air-Conditioning

IAQ : Inside Air Quality

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Thank you for your interest and attention …. Please contact me at my e-mail below

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