Cooling Down the 'Fair' Way

Cooling buildings without heating the planet: why Air Conditioning India is not enough, why we must **'Fair' Condition** it

the **Head**

- *Economy*
- *Environment*

the **Heart**

- *Responsibility*
- *Justice*

the **Hands**

- *Targets*
- *Solutions*

the Head –
Environment & Economy

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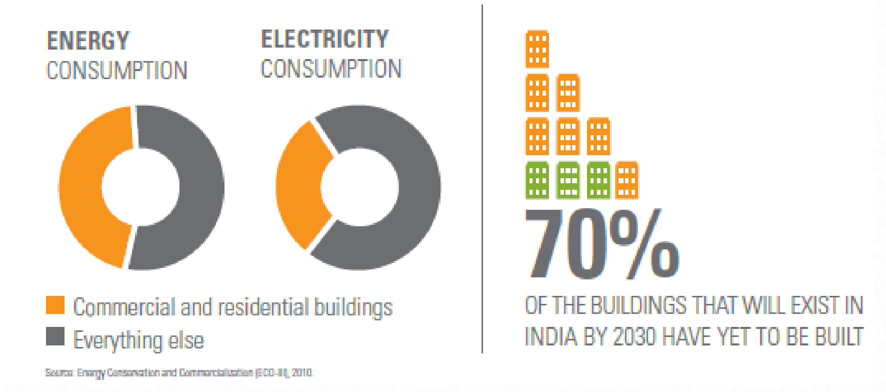
the Head - *Economy*

Figure 2. Building Energy Consumption in India



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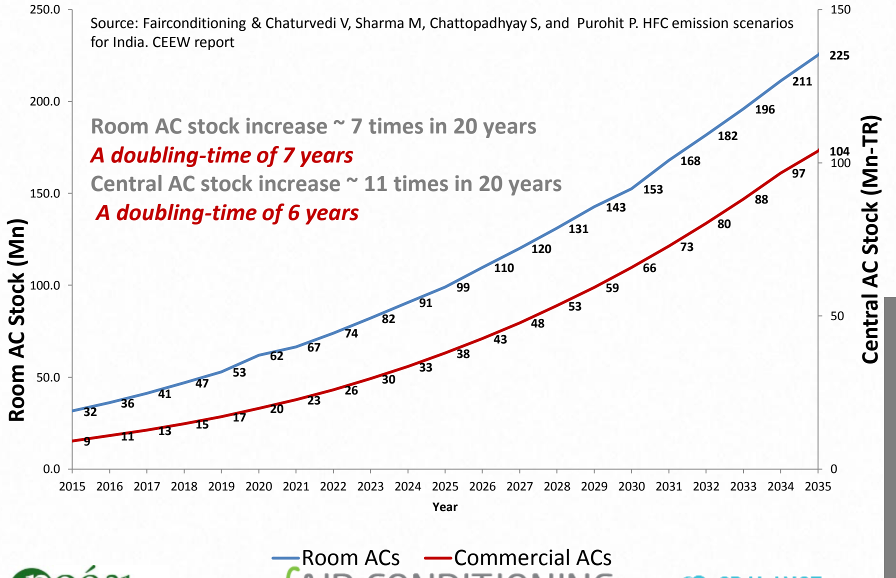
the Head - *Economy*

India's AC Stock Projection - 2015 to 2035



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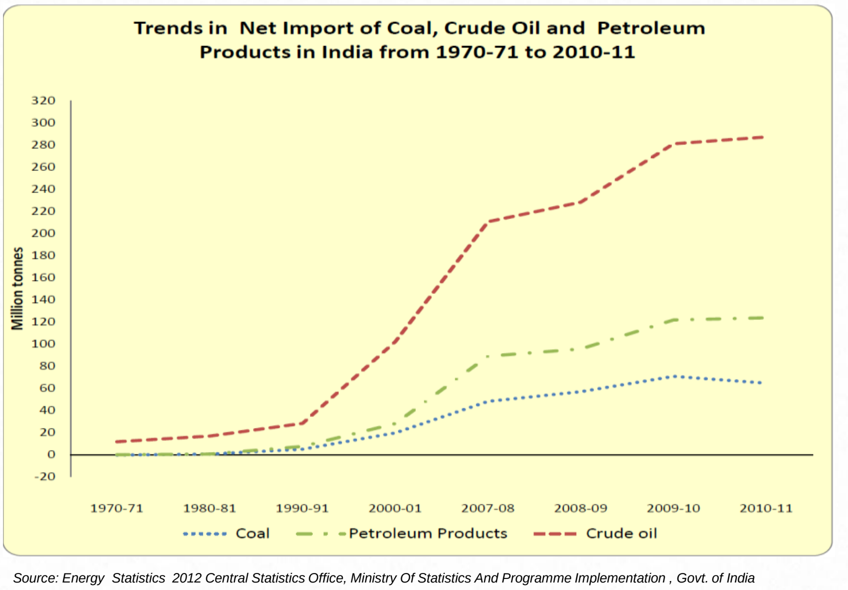
the Head - *Economy*



Source: Energy Statistics 2012 Central Statistics Office, Ministry Of Statistics And Programme Implementation , Govt. of India

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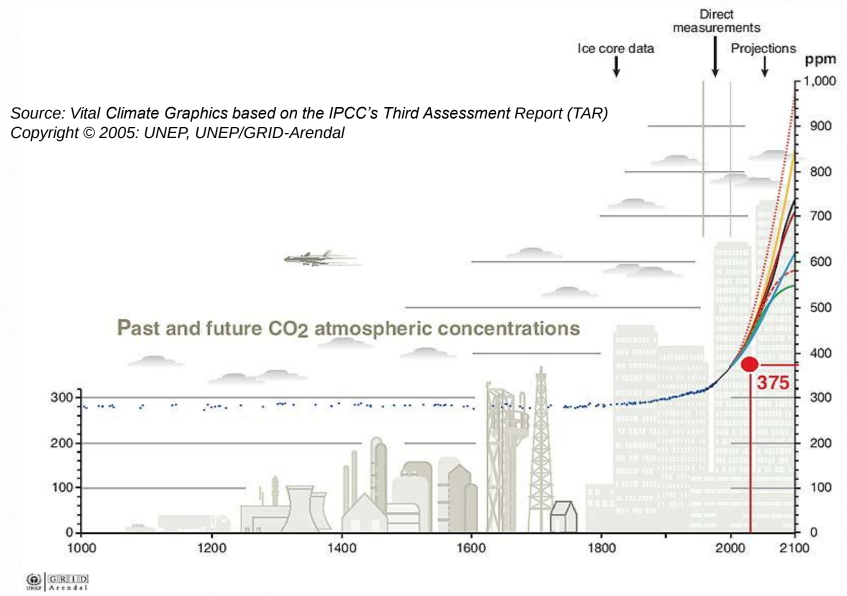
the Head - *Environment*



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the Head - *Environment*

Increased Refrigerant Emissions

Refrigerants	Type	GWP (100 Year, AR 2007)
R410A – R32/R125 – 50:50	HFC	2088
R22 – Chloro Difloro Methane	HCFC	1810
R134A – Chloro Difloro Methane	HFC	1430
R32 – Methylene Fluoride	HFC	675
R290 – Propane	HC, 'Natural'	3.3[16]
R1270 – Propylene	HC, 'Natural'	1.8[16]
R744 – Carbon Dioxide	'Natural'	1
R717 – Ammonia	'Natural'	0

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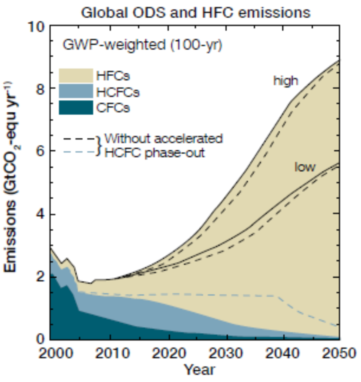
the Head - *Environment*

Increased Refrigerant Emissions

Fig 1: **Growing HFC emissions**

This graph shows that while CFC and HCFC emissions go down (the light-blue blocks), HFC emissions (the light-brown block) will overtake them by around 2025, and rapidly increase up towards 2050.



SOURCE: Velders et al, 2009

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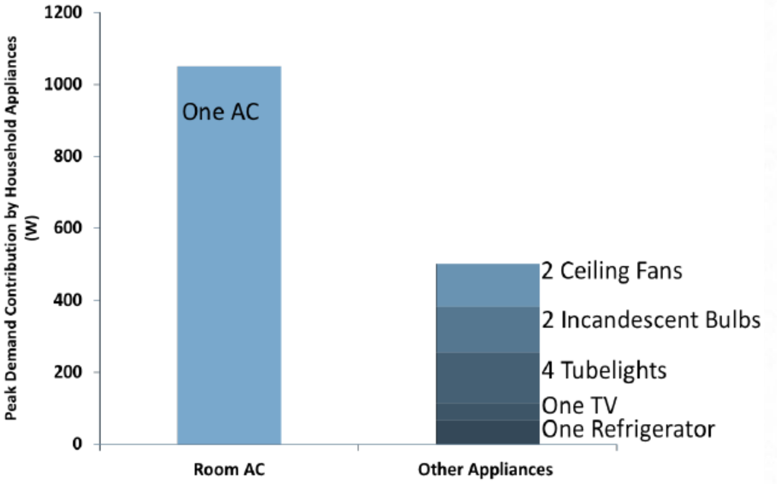
the Head - *Environment*

ACs dominate residential building energy consumption



Source: LBNL, Smart and Sustainable Space Cooling Alliance, Alliance for an Energy Efficient Economy, 2016

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the Head - *Environment*

In 2030

AC GHG Emissions from India ~ 338 Million Tonnes CO2e per year

~ **1.35 Billion Trees** required per year

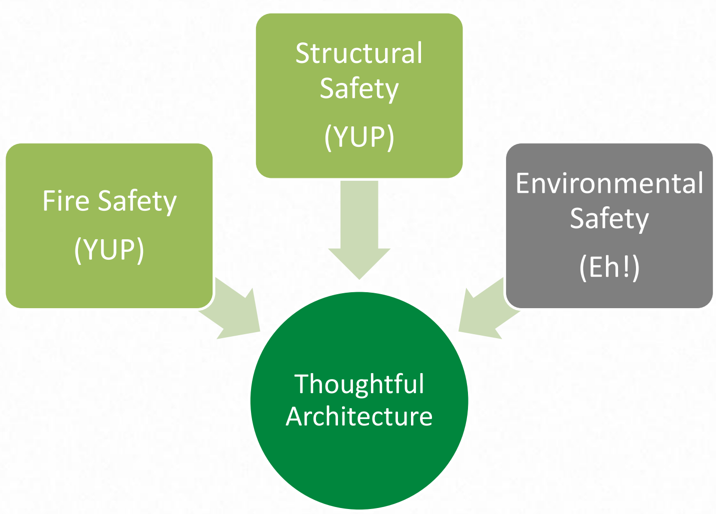
Source: Fairconditioning

the Head – *Environment & Economy*

> Built Space ✖ > AC Space % ✖ > AC Energy + Ref. Use = **> GHG Emissions**

the Heart – *Responsibility & Justice*

the Heart - Responsibility



Reality check:
Its a **humanitarian** issue, not 'just' an **environmental** issue

the Heart - *Justice*

Vulnerable Region	Migrant Levels in 2100
West Bengal	~10 million
Coastal Maharashtra (around Mumbai)	~10-12 million
Coastal Tamil Nadu	~10 million
Coastal Andhra Pradesh	~6 million
Gujarat	~5.5 million
Coastal Orissa	~4 million
Western Rajasthan	~1.4 million
Northern Karnataka	~1.3 million
Madhya Pradesh	~1.2 million
Interior Maharashtra	~1 million
Northern Andhra Pradesh	~1 million
Southern Bihar	~1 million

TABLE 3.
REGIONS IN INDIA THAT WILL LIKELY EXPERIENCE THE HIGHEST LEVELS OF OUT-MIGRATION DUE TO SEA LEVEL RISE AND DROUGHT/GLOBALIZATION.

CLIMATE MIGRANTS IN SOUTH ASIA: ESTIMATES AND SOLUTIONS

Department of Humanities and Social Sciences, Indian Institute of Technology Madras.

the Hands –
Targets & Solutions

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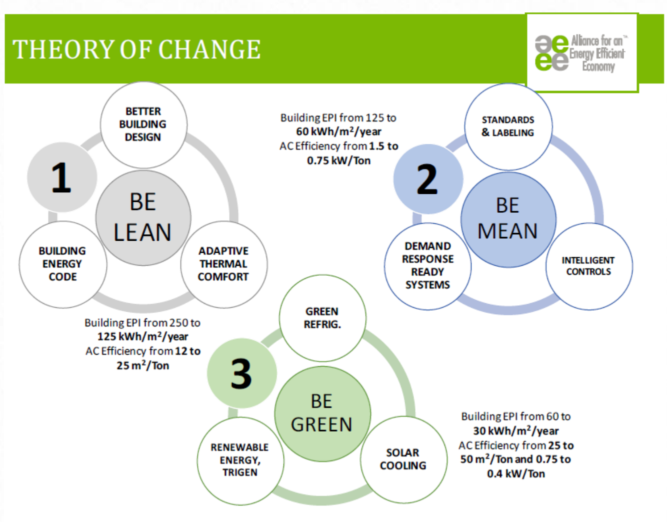
the Hands – Solutions



Source: LBNL, Smart and Sustainable Space Cooling Alliance, Alliance for an Energy Efficient Economy, 2016

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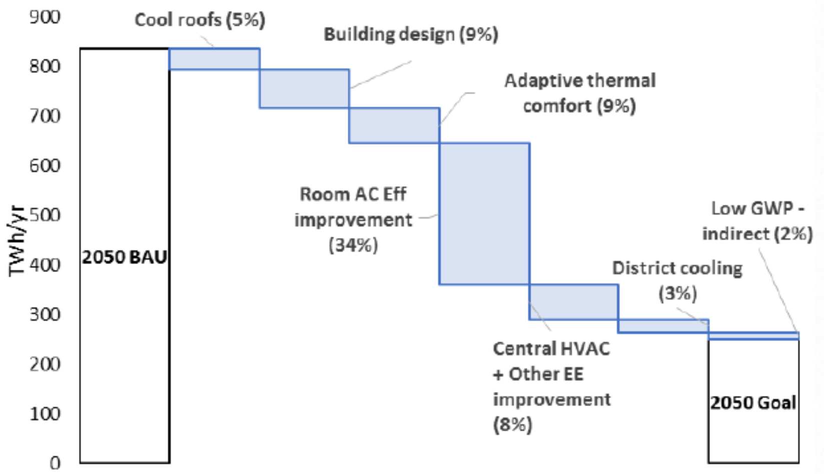
the Hands – Solutions

Application of thoughtful design principles (building & systems) = 70% reduction of cooling energy



Source: LBNL, Smart and Sustainable Space Cooling Alliance, Alliance for an Energy Efficient Economy, 2016

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the Hands – Solutions

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Sustainable Cooling Technologies:
Structure Cooling

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Why Structure Cooling

Three Questions?

1. What is the merit of cooling a place using **AIR**, a good insulating medium, with low thermal capacity?

2. If you want to empty a tank, do you **pump** it out or would you rather **drain** it?

3. Which heat transfer process would you choose: A or B?
A: linearly proportional to temperature difference (i.e. doubling Δ T = 2 x heat transfer rate)
B: proportional to **4th power** of temperature difference (i.e. doubling Δ T = 16 x heat transfer rate)

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Why Structure Cooling

	Thermal Conductivity (W/mK)	Specific Heat Capacity (W/kg.k)	Density (kg/m^3)
Air	0.03	1.004	1.225
Water	0.6	4.18	1000

Thermal capacity (heat absorption per unit volume):
Water ~ 3400 x Air

Medium	Cooling Capacity	Flowrate Required	Power Required
Air	100 TR	~ 40,000 cfm	22 kW
Water	100 TR	~32 cfm	3.7 kW

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Why Structure Cooling?

The most evolved 3-pronged technique to achieve thermal comfort using no energy:

1. Create barriers: *trees, verandahs, hollow walls, stone screens*
2. Build massive structures and use them as thermal capacitors: *thick walls and high ceilings*
3. Drain out the stored heat: *water bodies in contact with the plinth and by special plasters that promoted radiation to the sky*

Why Structure Cooling?

1. Unreasonable desire for maximizing carpet area for a given built up-area, eliminates High Thermal Mass.

2. Water is a scare resource and hence creating water bodies / streams and circulating them through a building is not feasible.

3. A modern manifestation of above features which adheres to the techniques but enhances the technology, is **Structural Cooling.**

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Working Principle

Conventional Air-Conditioning Systems:
• Rely on thermal conductivity and forced convection of air: A warm molecule of air comes into contact with another cooler molecule thereby resulting in transfer of energy from a warmer to cooler space
• Pump heat from a lower-temperature region (inside) to a higher temperature region (outside)

Structure Cooling Systems
• Occupants feel comfortable in spaces if surrounding surface temperatures are below body temperature: the body looses heat spontaneously
• Works on radiation and convection heat transfer eg. in ceiling cooling, 50% cooling output through convection, 50% through radiation
• Not just about providing a cool-surface to radiate heat into (i.e. radiant cooling), it directly 'drains' solar heat load from the structure

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Working Principle

- Air is a good medium for convective heat transfer
- Became mainstay of air conditioning (largely 'air heating' systems such as heat-pumps) in Northern Temperate climates; low thermal-mass yields high temperature increase with minimal heat energy input
- For cooling, draining away the heat directly from the structure using a little warm water is better than allowing it to enter the structure and pumping it out by a lot of chilled air.
- Conventional Air Conditioning suitable for a heating dominated climatic context; not cooling-dominated regions.

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Working Principle

Factors affecting Thermal Comfort:

1. Dry Bulb Temperature
2. Relative Humidity
3. Airspeed
4. **Mean Radiant Temperature**
5. Metabolic Rate
6. Clothing

Reference: ANSI/ASHRAE standard 55 thermal environmental conditions for human occupancy

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Science Principle

SEC. 16.3] SOME EFFECTS OF THERMAL ENVIRONMENT 387

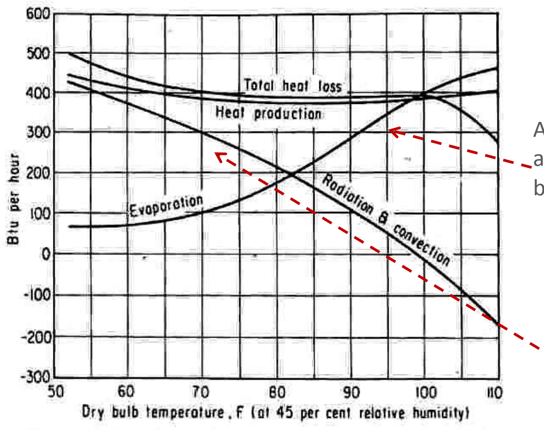


Figure 16.1 Body heat production and environmental heat exchanges for a healthy, young, clothed man seated at rest. (Adapted by permission from *Heating, Ventilating, Air Conditioning Guide*, Vol. 37, p. 63.)

Study by ASHRAE

At skin temperature or above, the only way to lose body heat is by perspiration.

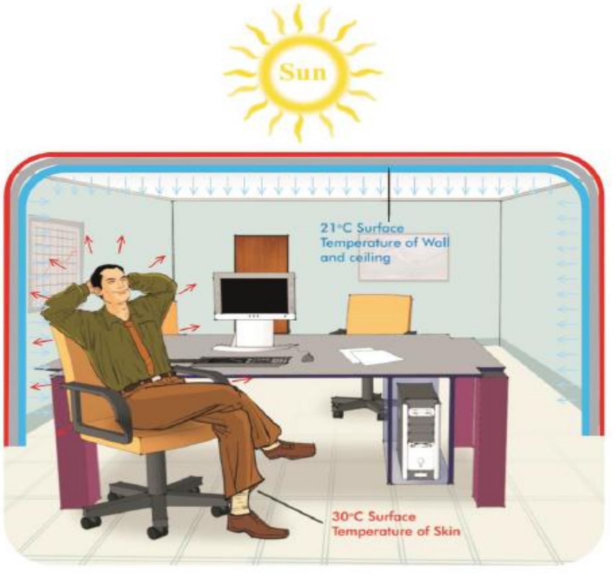
At low MRT, most body heat is lost by radiation& convection

Science Principle

Studies of Thermal Behaviour of Buildings and Occupants conclude:

Building Designers must keep the MRT well below the skin temperature

Working Principle



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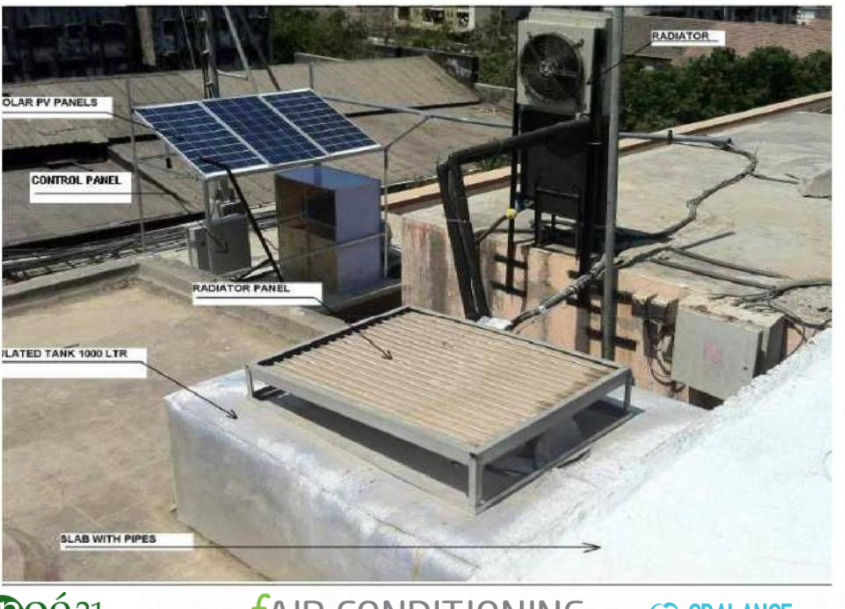
Operation Mechanism



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Operation Mechanism

Step 1: Pump in the insulated, partitioned tank circulates water.

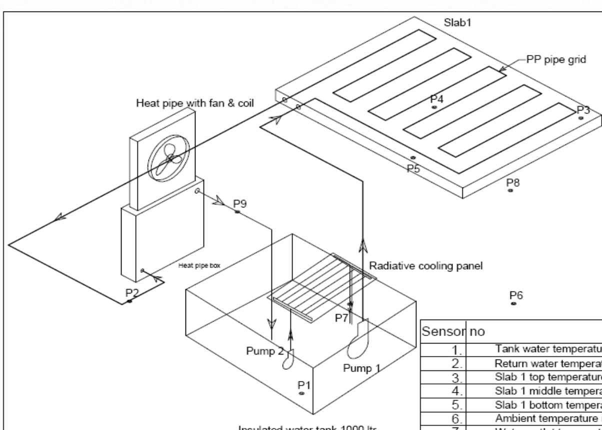
Step 2: Water picks up heat from the slab

Step 3: Returning water is cooled by a fan cooled heat pipe on its way to the tank.

Step 4: Returns to the same tank, closing the loop

Step 5: At night, radiative panel lowers tank temperature by direct radiation to the sky. Cooled water ready for the next day's cycle.

Operation Mechanism



Sensor no	Discription
1.	Tank water temperature
2.	Return water temperature from grid or Supply water temp to Heat pipe
3.	Slab 1 top temperature
4.	Slab 1 middle temperature in a copper tube
5.	Slab 1 bottom temperature
6.	Ambient temperature in sunlit
7.	Water outlet temperature from Radiant panel
8.	Temperature near Slab 1 bottom or Ambient temperature in shade
9.	Water outlet temperature from heat pipe to the Water tank
10.	Slab 2 bottom temperature

Application

Step 1: Lay 25mm dia. corrugated polypropylene pipe in a joint-less continuous loop over the bare slab.

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Application

Step 2: Cover the pipe loop with a 50 mm screed/ Water proofing to be done over it.

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Application

Step 3: Connect the submersible pump in the tank to the loop, heat pipe and back to the tank

Radiator and Tank

Header

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Application

Step 4: One square meter sheet of aluminium. With a serpentine copper coil attached to it. Coated with a barite rich paint resulting in high emissivity.

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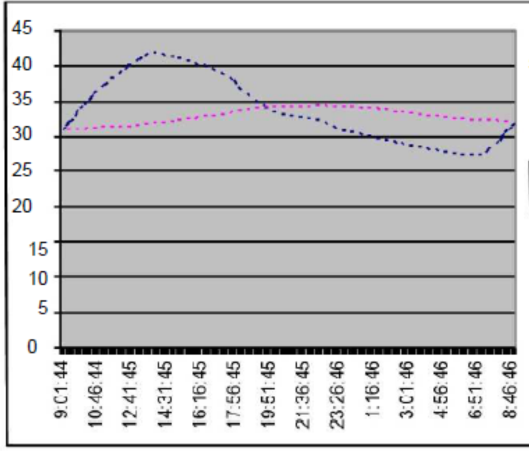
Application

Data Logger Recordings



Top and bottom slab temperatures with cooling systems off.

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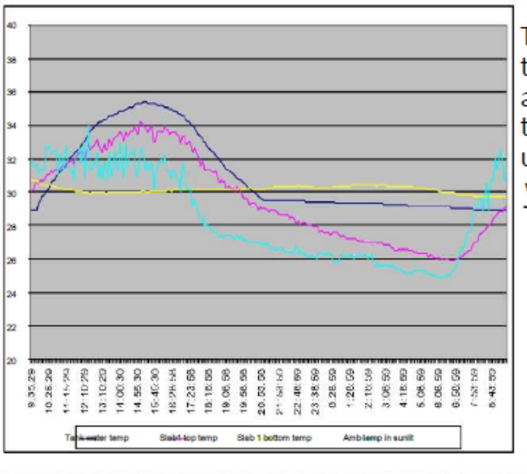
Application

Data Logger Recordings



Tank water, slab top and bottom, and ambient temperature under sunlight with the system.

After switching the heat pipe on, the slab bottom temperature remained at 30 deg. C.

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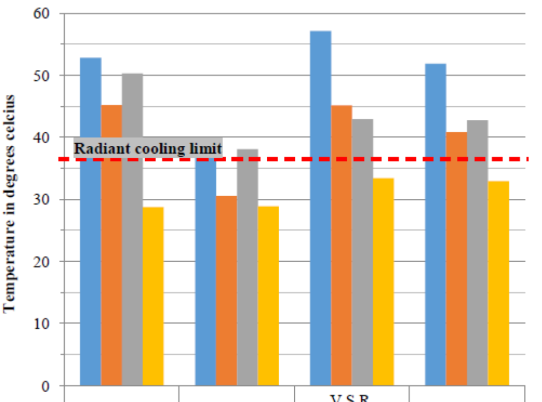
Application



	Kabra House	Pilot Project	V.S.R. Smarak	Indigo Office
Avg. Roof top	52.80	38.09	57.14	51.88
Avg. Roof bottom	45.20	30.56	45.16	40.86
Avg. Roof top w/ D.S.C	50.28	38.09	42.92	42.76
Avg. Roof bottom w/ D.S.C	28.73	28.90	33.39	32.96

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Application

Comparison of peak values at roof (temperatures in degrees celcius)						
	Roof			Load reduction		
	Top Side	Under Side	Difference	Surface temperature	Room design	Difference
Slab A1	48.0	34.0	14.0	34.0	24	10.0
Slab A2	42.0	33.1	8.9	33.1	24	9.1
Slab B1	57.1	45.2	11.9	45.2	24	21.2
Effect on cooling load if air conditioned				**Reduction in A1**		**11.2**
				Reduction in A2		**12.1**
				Percent savings in A1		**24.78**
				Percent savings in A2		**26.77**

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Application

For Temperate Climates (requiring Heating & Cooling)

• This system can be used for heating the floor in winter (if the floor is poured concrete).

• The main system set-up will be the same except an extra solar water heater will be installed to heat the water in underground tank.

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Application

Veer Savarkar Smarak Mumbai

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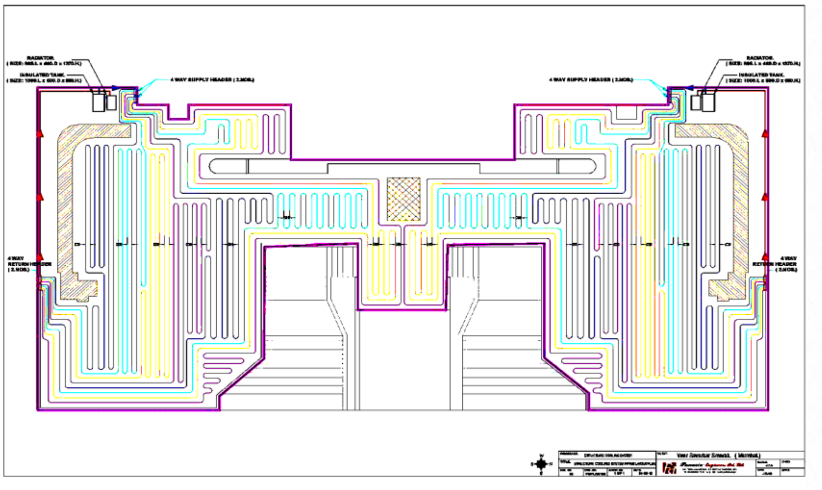
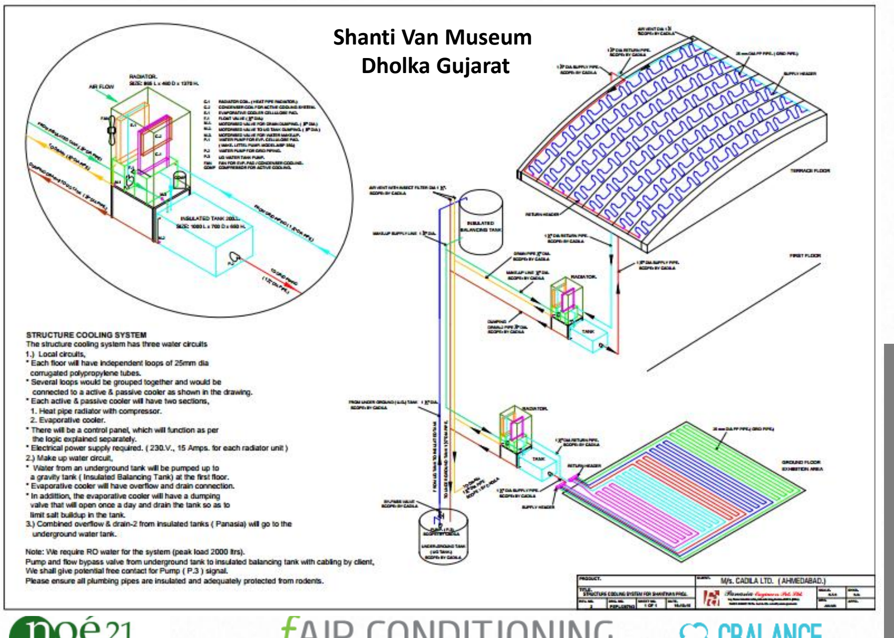
Application

Veer Savarkar Smarak Mumbai

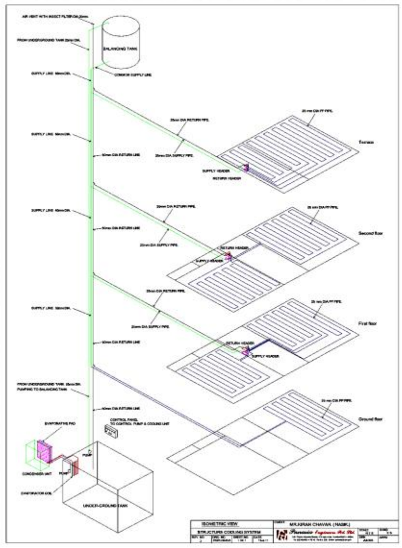


Application



Application

Multi Story System at an Office at Nashik



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Application

ATE Factory, Sari (Gujrat)

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Application

Shrujan Living, Learning and Design Centre, Kutch (Gujrat)

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Application

Shrujan Living, Learning and Design Centre, Kutch (Gujrat)

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Benefits

- Impedes solar heat gain from roof and floors by absorbing it before causing thermal discomfort to occupants; thermodynamic heat sink.
- Able to maintain floor temperature below human skin temperature on hottest summer day.
- Cool floor and ceiling reduce (i.e. low Mean Radiant Temperature) enhances comfort for the same temperature and humidity.
- During night time, further cooling of structure through night sky radiation.
- Closed circuit; no evaporation and no loss of water.
- Only active elements are a pump & fan; use negligible energy that Solar PV Panel can address.
- All components are locally available; no prohibitive patents
- Pipes do not have to be embedded while casting slabs; allows retro-fit.

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Benefits

- Approximate cost benefit analysis

Parameter	Conventional	Hybrid (Structure + Convent. System)	Units
Cooled Area	1,076	1,076	sq. ft.
Conventional sq.ft./TR	165	165	sq. ft./TR
Conventional TR	6.52	6.52	TR
% (Solar + Sensible Load) vs. Total heat Load	NA	50%	
COP	2.93	2.93	COP
Total Power Requirement	7.82	5.06	kW
Effective COP	2.93	4.53	COP
Capital Cost Factor (Latent + Sensible)	19,286	19,286	INR/TR
Capital Cost Factor (Solar)		112	INR/sq.ft.
Total Cost	125,766	182,883	INR
Technology Level Price	19,286	28,044	INR/TR

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