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Radiant Cooling Support Brochure for Architects

May 2016 Extended Edition

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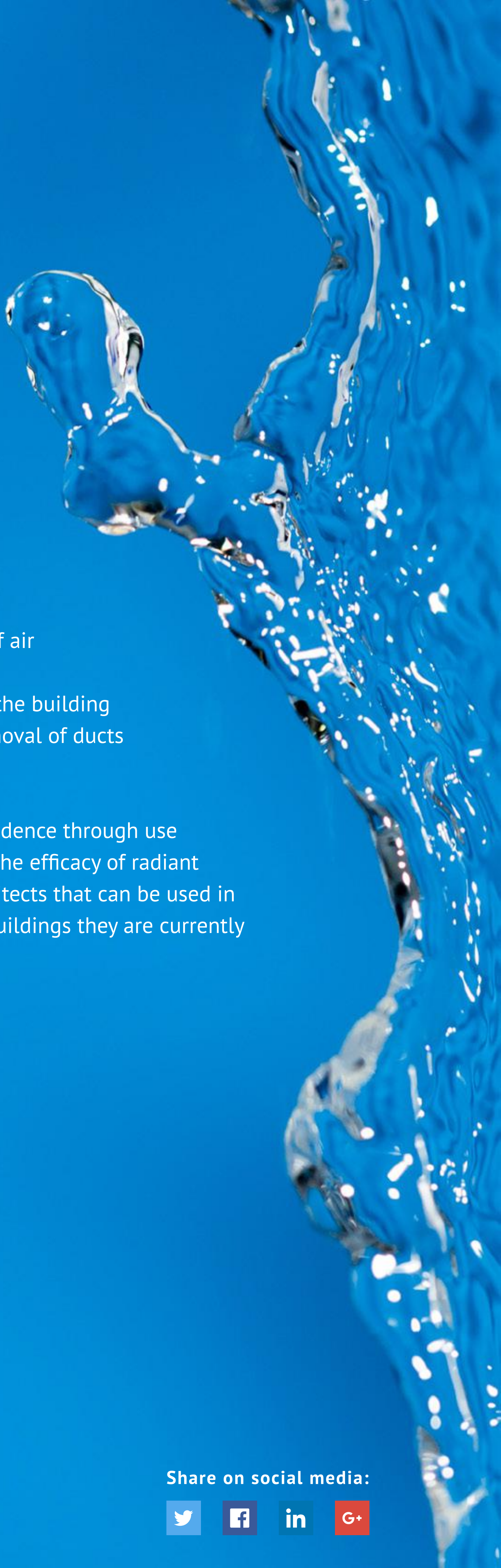
Executive Summary

It was found that in comparison for use in commercial buildings in humid climates, when compared to conventional All-Air solutions, Air-and-Water (radiant) solutions are:

- More sustainable and efficient
- More cost effective as a result of the ongoing energy savings
- Able to provide greater thermal comfort to occupants
- Able to provide greater architectural freedom due to the reduction in the number of air ducts required compared to All-Air systems
- Able to either dramatically reduce the cost of the building or provide more usable floor space, due to removal of ducts and subsequent decrease in ceiling height

The purpose of this brochure is to first provide evidence through use of a case study regarding the claims made about the efficacy of radiant cooling, and finally, to outline the systems to architects that can be used in order to implement radiant cooling solutions in buildings they are currently designing.

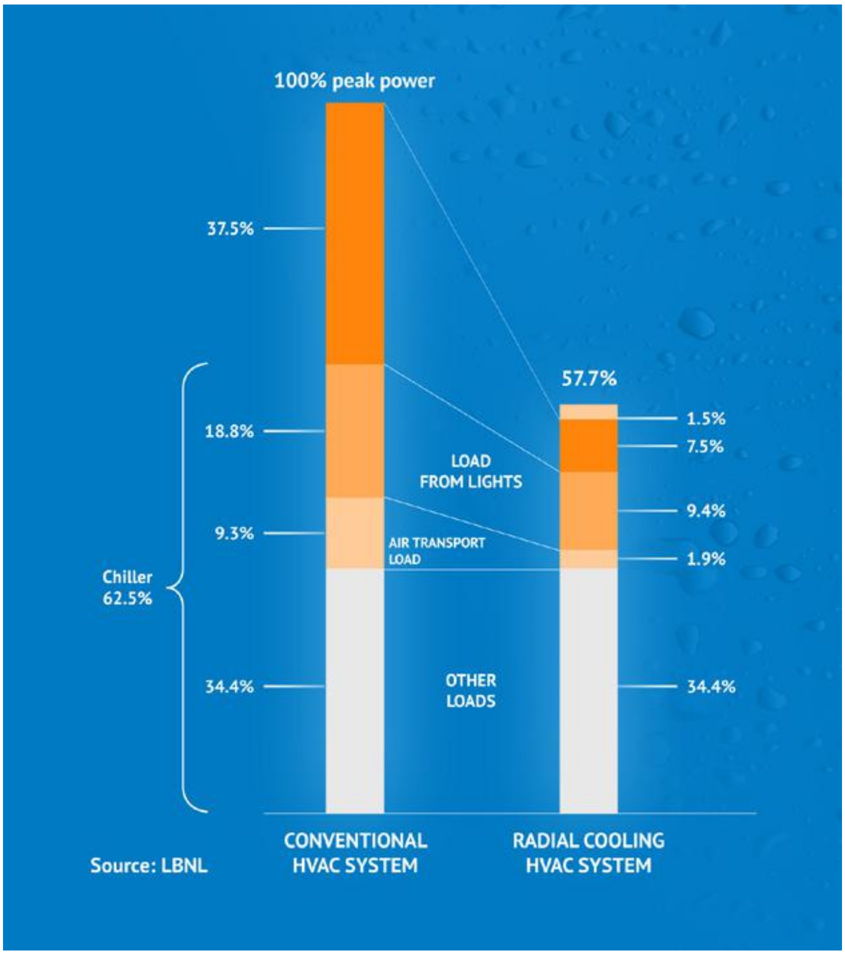


1. Summary of Air-and-Water Systems

Air-and-Water Systems

Like All-Air systems, Air-and-Water systems are also designed to maintain indoor air quality and provide thermal space conditioning. However, to do that they are required to separate the tasks of ventilation and thermal space conditioning by using:

- **The air distribution system to fulfill the ventilation requirements and cover latent loads and remove moisture from the space. In addition, cover any additional sensible loads.**
- **The water distribution system to thermally condition the space by removing sensible loads through radiant cooling.**



These systems reduce the amount of air transported through buildings significantly, as the ventilation is provided by outside air systems without the recirculating air fraction. The cooling is provided mainly by radiation using water as the transport medium, which is far more efficient than by air due to higher specific capacity.

Due to the separated control of each parameter responsible for thermal comfort, merged in a combined control, thermal comfort and indoor air quality are improved immensely. In short, Air-and-Water systems combines controlled temperature of room surfaces via radiant cooling with central air handling systems.

Air-and-Water System Power Consumption

The radiant cooling system portion of Air-and-Water systems is responsible for thermal conditioning. Due to the physical properties of water, radiant cooling systems can remove a given amount of thermal energy using less than 5% of the otherwise necessary fan energy.

In addition, due to the large surfaces available for heat exchange in radiant cooling systems, the chilled water temperature is close to the ambient temperature and allows to adapt to renewable energy such as heat pumps, injection wells and free cooling by heat exchange to outside air during the night. If standard chillers are used it leads to a better COP.

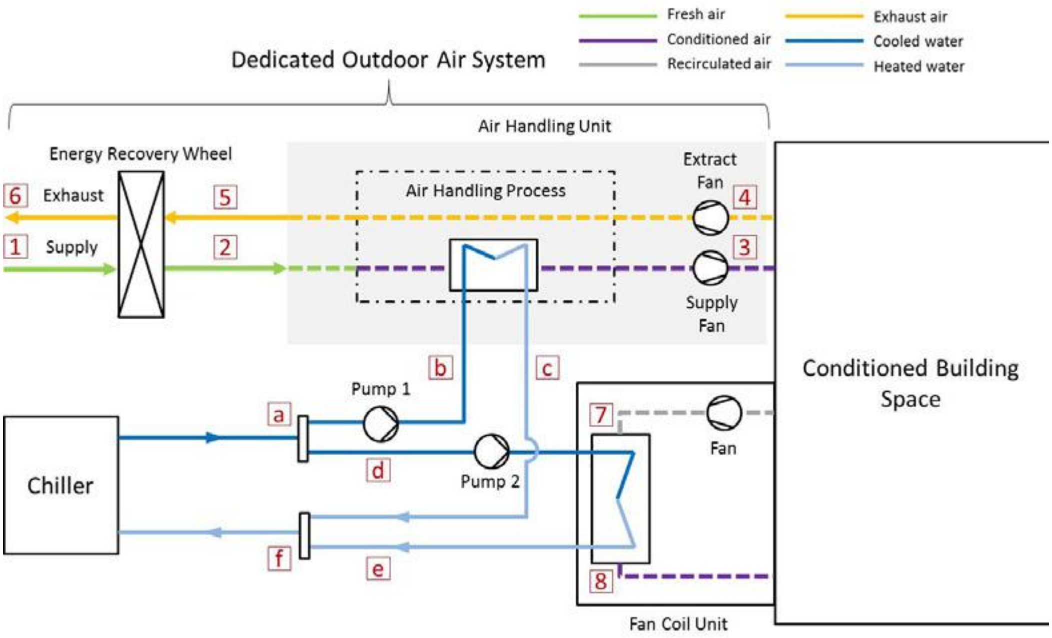
At the same time, radiant cooling systems reduce maintenance compared to All-Air systems, since radiant systems are maintenance free. The ventilation system in combined used with a radiant system in an Air-and-Water system is way smaller and therefore also reduces maintenance cost.

2. Malaysia Case Study

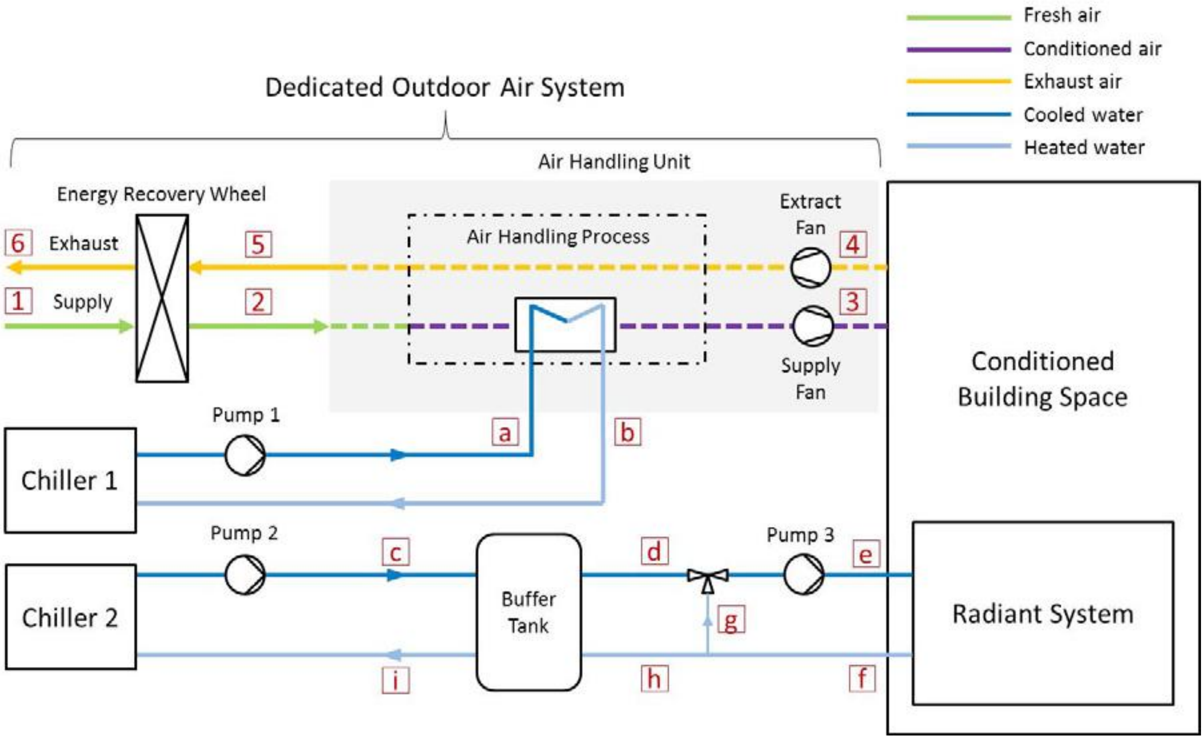
Introduction to the Uponor Malaysia Case Study

In order to fully illustrate how effective radiant cooling can be at both reducing the cost and energy consumption of nonresidential buildings in humid climates, an economic analysis of a 30,525m^2 commercial building in Kota Kinabalu, Malaysia that uses the Uponor 'TABS' system for cooling is presented.

The original fan coil unit (FCU) system & dedicated outdoor air system (DOAS) in the building is compared to the existing radiant system & DOAS are compared to provide a useful benchmark. The DOAS & increased air flow was used to cover all latent loads and higher cooling loads during events. The radiant system was used for base cooling.



Radiant System + DOAS Cooling



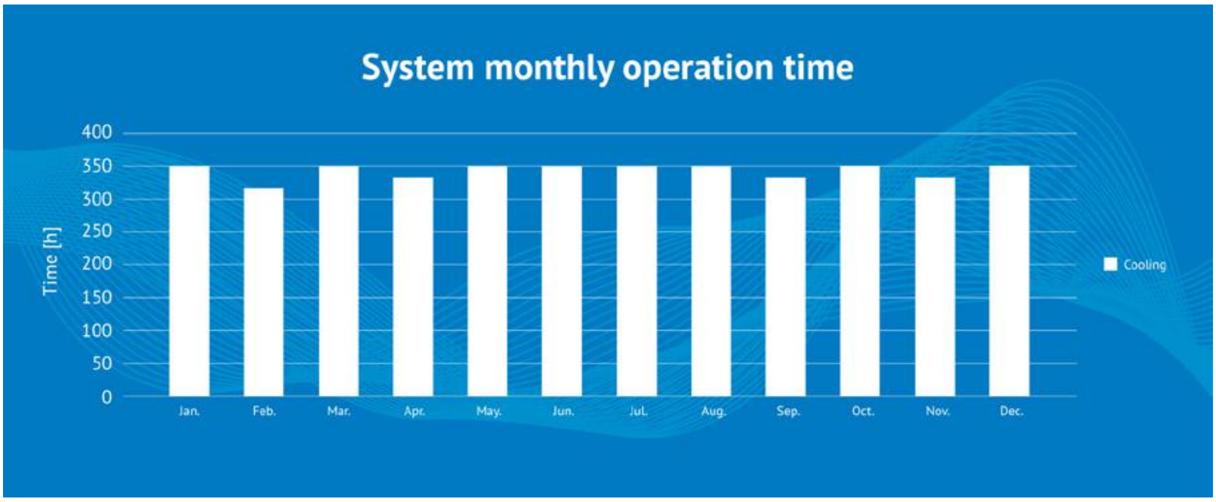
Boundary Conditions

Calculation Tool of Economic Performance Comparison of Indoor Climate Systems

Operation Time Calculation											
User Input Data											
Location										**Kota Kinabalu**	
Building type										Commercial	
Conditioned area							m²			30525	
Building occupancy							Person			2000	
Fresh air rate per person							m³/person*h			30,0	
Period of return on investment							a			20	
Period of life cycle cost calculation							a			20	
Currency exchange rate							MYR/EUR			4,20	
Monthly Average Temperature [°C]											
Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
27,7	28,1	28,5	28,6	28,7	28,4	28,0	28,0	27,9	27,8	27,7	27,5
Cooling										convec.	radi.
Design indoor temperature							°C			23,0	25,0
Design indoor humidity							%			55,0	
Average specific demand							W/m²				
Radiant system type											
Design outdoor temperature							°C			33,7	
Design outdoor humidity							%			64,4	
Local atmospheric pressure							Pa			101060	

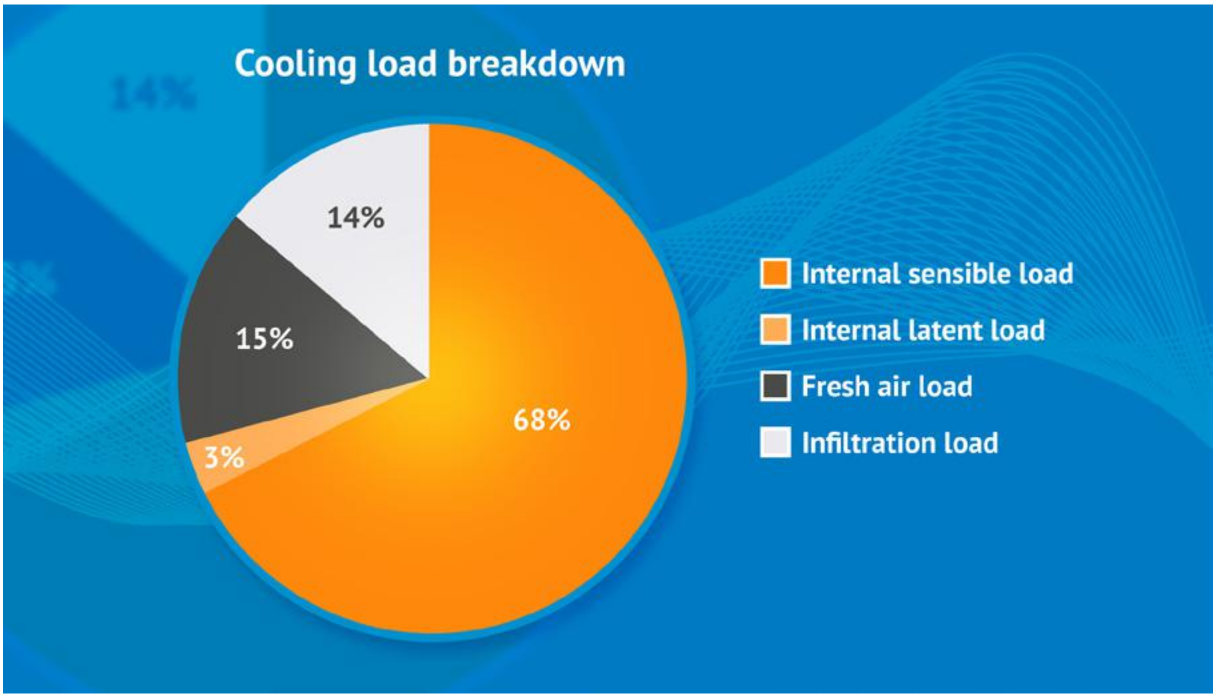
Operation Time

Operation Time Calculation														
Degree Day														
Boundry condition		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot./ave.
Days per month	day	31	28	31	30	31	30	31	31	30	31	30	31	365
Weekdays per month	day	22	20	22	21	22	22	22	22	21	22	21	22	259
Time correction factor		0,71	0,71	0,71	0,70	0,71	0,73	0,71	0,71	0,70	0,71	0,70	0,71	-
Monthly average temp.	°C	27,7	28,1	28,5	28,6	28,7	28,4	28,0	28,0	27,9	27,8	27,7	27,5	28,1
Standard deviation	°C	0,93	1,01	1,07	0,94	0,99	0,94	0,99	0,95	0,92	0,87	0,89	0,95	0,95
Base outdoor temperature	°C	Cooling							20,0					
Operation condition		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot./ave.
Days in need of cooling	day	31,0	28,0	31,0	30,0	31,0	30,0	31,0	31,0	30,0	31,0	30,0	30,1	365
ΔT to be cooled	°C	7,7	8,1	8,5	8,6	8,7	8,4	8,0	8,0	7,9	7,8	7,7	7,5	96,9
Performance degree	%	89	93	98	99	100	97	92	92	91	90	89	86	93
System Monthly Operation Time Summary														
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Cooling	h	352	320	352	336	352	352	352	352	336	352	336	352	4144,0



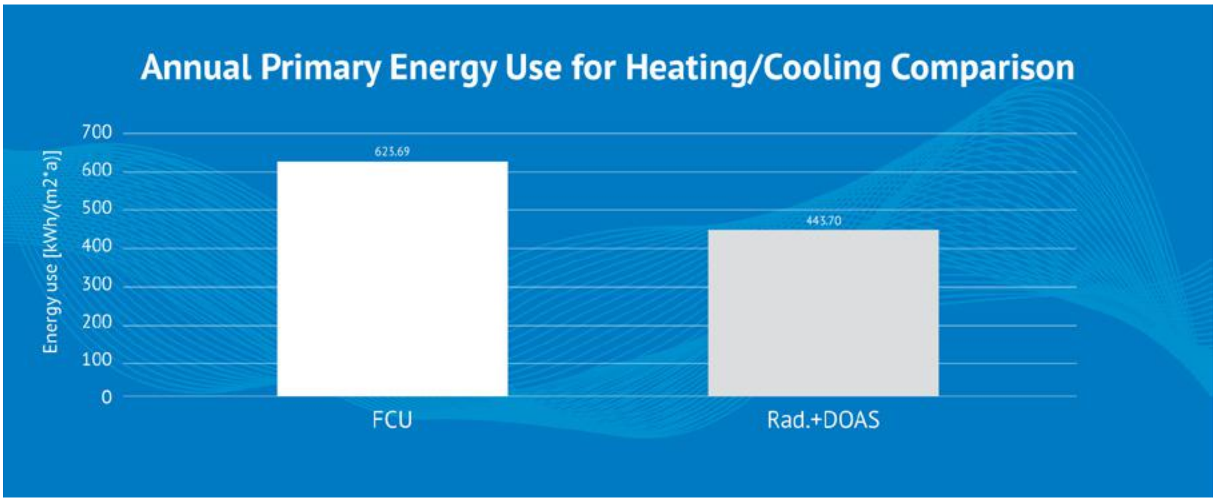
Cooling Load Breakdown

Cooling Loads Breakdown			
Internal sensible load	W/m²	90,0	67,7%
Internal latent load	W/m²	4,1	3,1%
Fresh air load	W/m²	20,4	15,4%
Infiltration load	W/m²	18,4	13,8%
Total	W/m²	132,9	100%



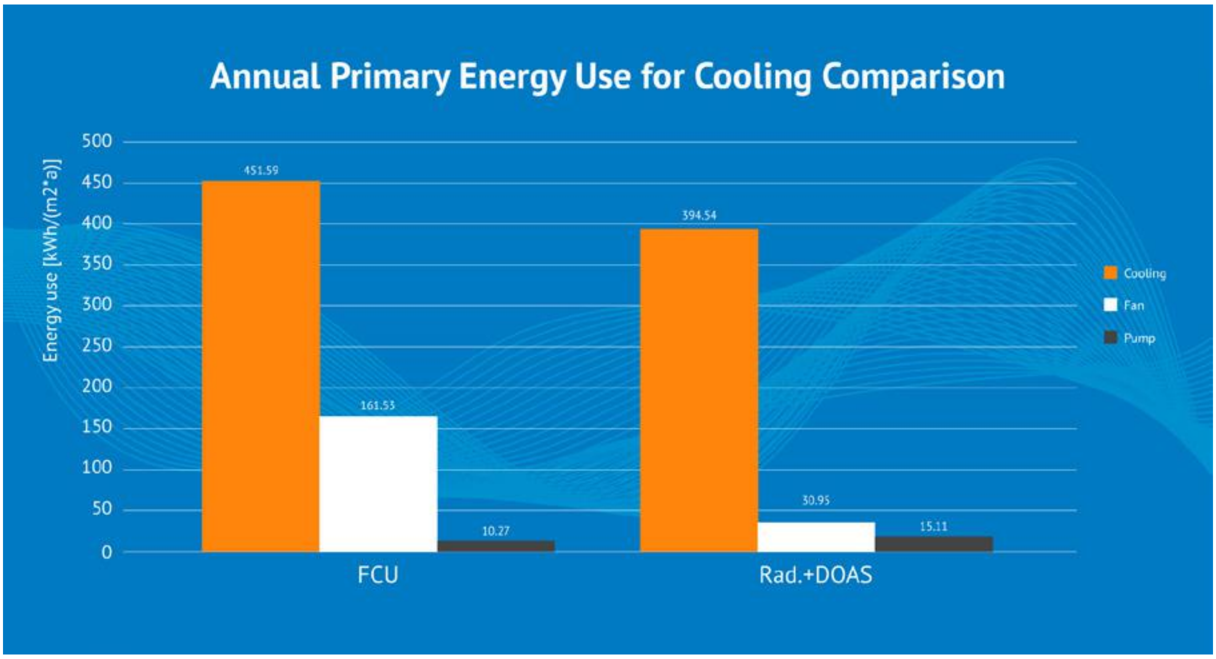
Energy Use Comparison

Energy Use Comparison		
Energy Use Comparison		
All electrical		Cooling
FCU	kWh/a	6346004
Rad.+DOAS	kWh/a	4514626



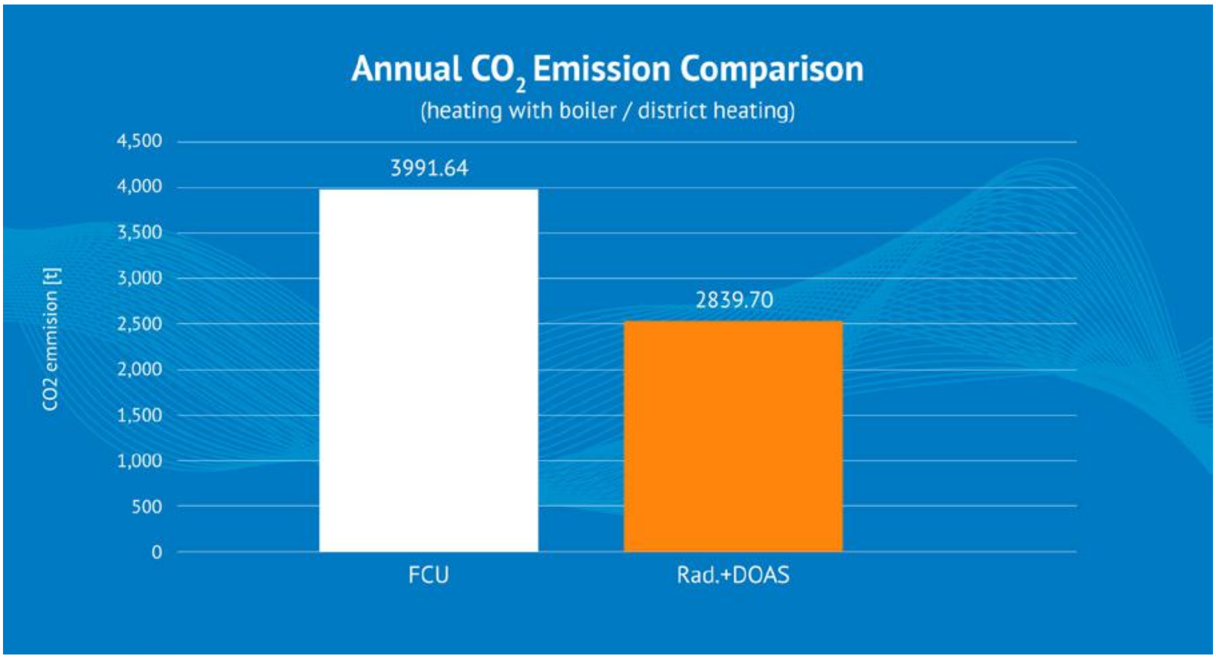
1,831,378 kWh/a less per annum was used in the radiant system against the FCU system.

Energy Use Comparison Breakdown



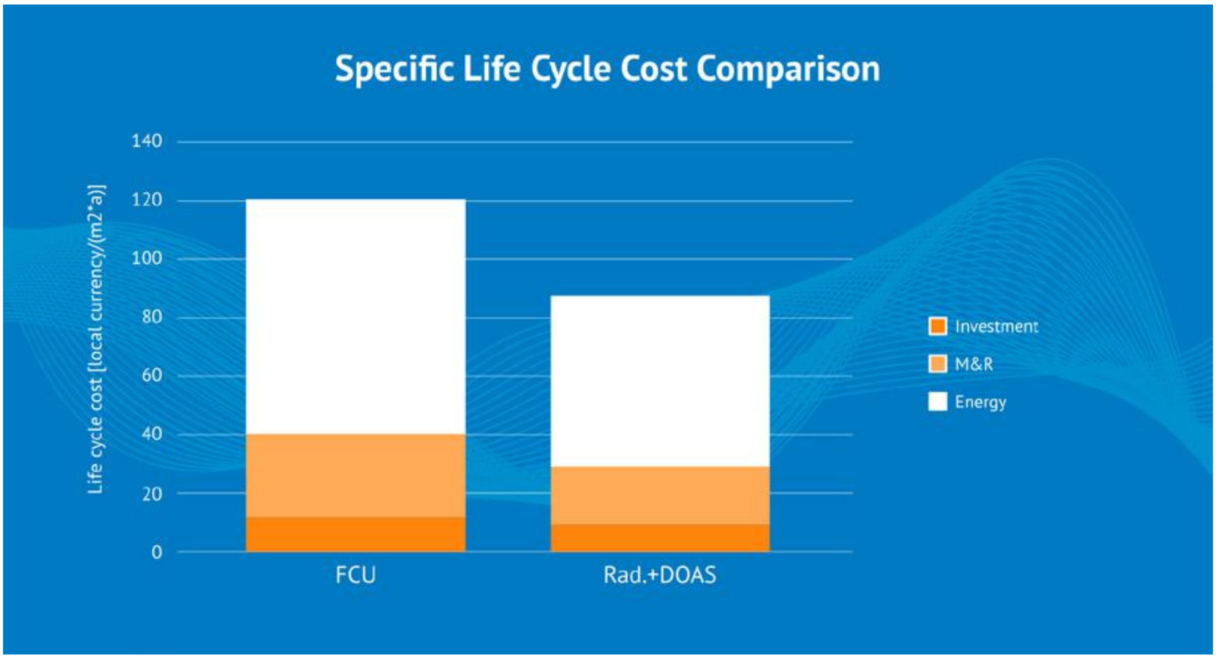
It is abundantly clear that both the chiller and fan use significantly less energy as part of an Air-and-Water system compared to the All-Air system. This is the key reason for the savings we see on the previous graph.

CO_2 Emissions



As a result of the energy savings, the CO2 emitted from the building is significantly less.

Life Cycle Cost Comparison



Malaysia Case Study Summary

It's abundantly clear from this case study that both energy and cost can be reduced by implementing radiant cooling in commercial buildings.

Crucially, this has been achieved without a degradation to the thermal comfort of the building, with an indoor temperature of 25°C and a humidity of just 55%.

3. A Case For The Implementation of Air-and-Water Systems in Commercial Buildings in South East Asia

Competing Interests

In considering using new technologies in building design, architects are confronted with a number of, often competing, requirements from a number of different stakeholders such as:

- Is this technology cheaper to install than alternatives?
- What are the installation lead times for this technology?
- Is this technology cheaper to maintain than alternatives?
- Does this technology last longer than alternatives?
- Are existing contractors able to install and maintain this technology?
- Does this technology create more usable floor space that can be leased out?

These are all pertinent questions, and in the case of cooling commercial buildings and a head-to-head analysis between All-Air systems Vs. Air-and-Water systems, it is clear from the Malaysian Case Study, Air-and-Water systems come out favourably. Moreover, when specifically considering indoor air quality and thermal comfort the following stakeholder concerns are also favourably addressed by Air-and-Water systems:

- Does the technology meet energy efficiency standards set by ASHRAE or EPC?
- Does the technology perform well in terms of:
    - Ability to maintain thermal comfort levels throughout the year?
    - Ability to maintain temperature and humidity levels below the dew point throughout the year to avoid condensation forming in the building?
    - Time it takes to achieve the optimum thermal comfort and humidity levels?

In this section, we will address the remaining concerns.

Installation Time, Cost & Expertise

Installation difficulty, time and cost depend on a number of factors in each building. Moreover, whether the building uses either a **high** (TABS = Concrete Core Activation Radiant system embedded in the core of the structural slab) or **low mass** installation (chilled ceilings) will impact the installation time, cost and expertise required.

The installation of chilled ceilings is part of the interior fit-out and done after the structure of the building is established. The installation is done by the contractor if the suspended ceiling in combination with the HVAC company responsible for the radiant system. The chilled ceiling systems are provided with a click-in (or push-in technology) and are very fast and reliable.

TABS systems are installed during the establishment of the building structure embedded in the core of the structural slab. The interface with the structural engineers requires more coordination, however with Uponor's modular solution an easy and quick installation can be guaranteed.

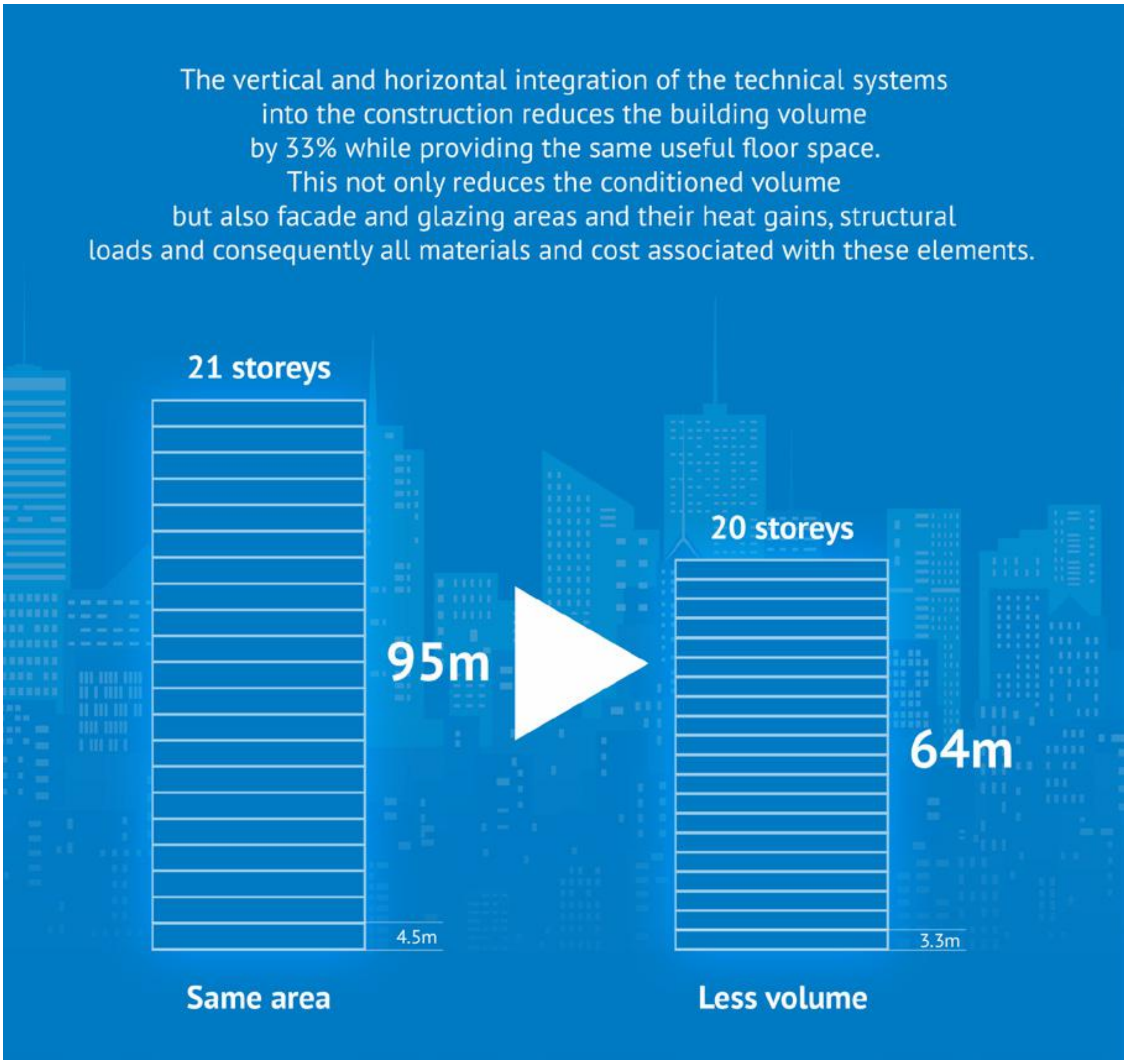
Uponor works closely with clients, design and engineering teams and provides a nominated design engineer on every project. Thus ensuring existing contractors are able to install radiant systems and are fully supported.

Maintenance Costs

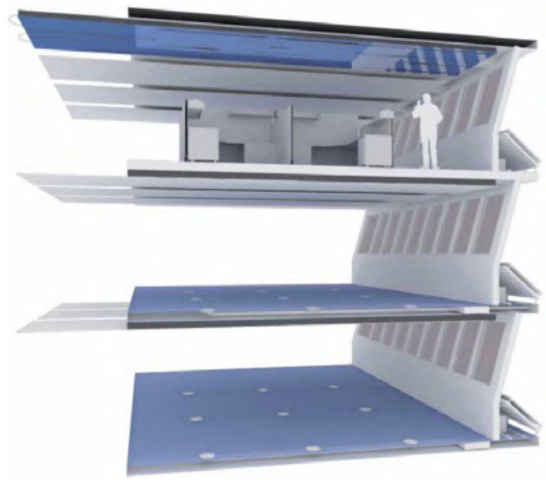
The annual cost of Uponor radiant cooling systems covers all maintenance, inspection, and cleaning, as well as minor replacements (e.g. filters) and is commonly calculated as a percentage of the investment cost for the whole mechanical system. However, the primary cost of maintenance relates to the air-side components. Compared to All-Air systems, these components are less in quantity or smaller in size in hydronic radiant cooling systems. The components related to the radiant system require almost no maintenance and most of them are covered by a 10 year guarantee.

Additional Floor Space

In new commercial buildings in South East Asia, up to one third of the enclosed volume is occupied by All-Air systems and structural elements, consuming valuable space. Large ceiling plenums are required to accommodate the high volume of ductwork needed for All-Air cooling systems, running below deep structural beams.



This practice results not only in large floor-to-floor heights that increases the volume of space to be enclosed and conditioned, but also in added material cost, higher structural loads and increased solar and transmission gains from additional façade surface. So, in addition to like-for-like energy and cost reductions, structural designs need to be made that increases spaces and wastes energy to accommodate All-Air systems.



Standard All-Air, packaged cooling systems in current use are typically oversized and over-cool the supply air in order to manage humidity levels, resulting in uncomfortable spaces with unnecessarily high energy demand. By switching from All-Air to Air-and-Water based systems, the space required for ventilation systems and their duct work are reduced by about 80% compared to the original space requirements.

Addressing concerns about condensation

Condensation can comfortably be managed in Air-and-Water systems. The cooling power of radiative heat exchange is limited by comfortable surface temperature according to standards and by the space dew point. In order to prevent condensation, chilled surfaces in buildings must be kept above the dew point at all operating conditions. Humidity sensors are used to monitor humidity in zones to constantly compensate the supply temperature of the radiant systems according the dew point. Therefore, condensation is not able to occur.

In Air-and-Water systems, to remove high thermal loads by means of radiation, one can manipulate the dew point easily by dehumidifying the supply air. Consequently, the surface temperature of the cooled area can be reduced to increase the operative temperature difference. However, precautions should be taken to keep within the specified comfort limits.

The alternative to reducing the dew point to avoid condensation involves automatically switching off the supply of cold water as soon as the relative humidity reaches excessive levels. In addition, buildings can be equipped with window contacts, cutting off the water supply when windows are opened and the ventilation system cannot guarantee trouble-free operation.

Addressing Performance Issues

In addition to thermal comfort factors, reaction times need to be taken into account when considering radiant cooling as a solution. For example, all systems working within thermal mass (high mass) are relatively slow in response to load changes. If however, operation allows the room temperature to fluctuate and cooling loads can be matched by these systems, they are the most energy efficient systems available.

Systems with water supply close to the chilled surface (low mass) have a response time comparable to All-Air systems.

Low Mass Panel Study of Reaction Time

In view of the fact that there are minimum external heat gains / losses in this case, the simulation was run for a two-day period only. The results of the course of the indoor air temperature (ti) and the mean radiant temperature (MRT) during these two days are shown below . This particular simulation was conducted with a room height of 270 cm and indoor air temperature at 26°C.

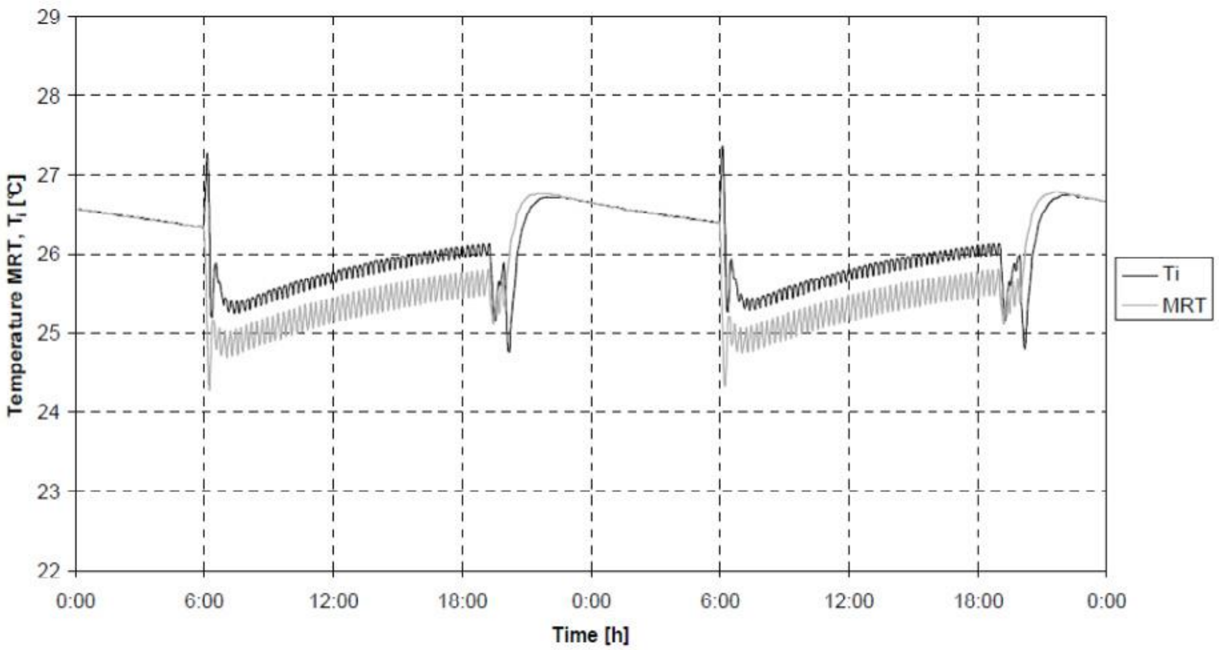


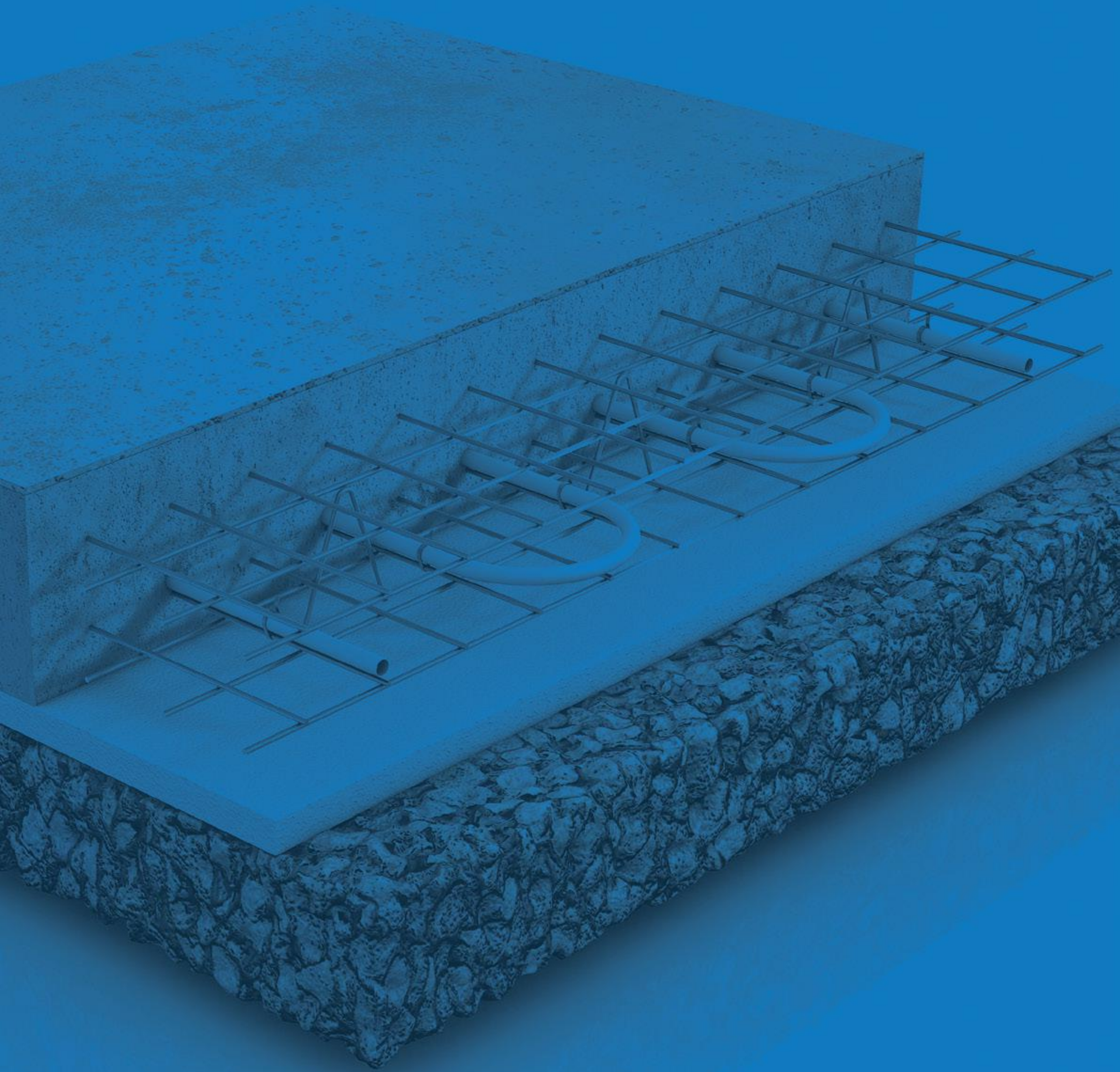
Figure 3: Mean radiant temperature (MRT) and indoor air temperature ti in the middle of the test chamber. The chamber (h = 270cm) is cooled from 6am till 8pm, the required air temperature is 26°C.

The cooling starts later than the effect of heat gains. The consequence is that the indoor air temperature increases at the beginning of the characteristic interval. After that a rapid decrease in air temperature is visible.

Oscillation of ti and MRT values at the end of the characteristic interval is caused by the assumed control procedure. During the night, when the room is not occupied and the cooling system is not active, the indoor air temperature becomes equal to the mean radiant temperature.

From this study we can clearly see that fast response times are achievable when using low mass panel radiant cooling in commercial buildings.

4. Uponor Radiant Cooling Solutions



A cooling solution for every need

Uponor understands the challenging nature of designing buildings in South East Asia. From battling the ever present humidity, meeting tight budget constraints on a buy-to-sell basis, to dealing with enforced changes to construction materials and technologies by building contractors, Uponor has a solution.

We offer a range of both high mass (embedded in concrete slabs) and low mass chilled ceiling solutions to meet those challenges for every budget and performance needs.

Uponor Tabs (High Mass)

Cooling and Heating in Offices and Commercial Buildings

Thermally **A**ctive **B**uilding **S**ystem for Cost and Energy Efficiency

In designing commercial buildings in South East Asia, ventilation, air-conditioning and cooling are essential components. Each one is a considerable task and investment in itself. Integrating indoor climate in the construction from the beginning can save a considerable amount in both terms of initial investment and future energy savings.

The Uponor TABS System operates with pipes embedded in the structural concrete slabs. This way, ceilings, floors and walls contribute primarily to the sensible cooling of the building. The embedded pipes activate the concrete core in the building mass for storage and discharge of thermal loads.

While the Uponor TAB System offers no native air-conditioning or ventilation capabilities, the task of conventional technologies is reduced to a minimum. Thus, when used in a hybrid Air-and-Water system, the best indoor environment possible is created in an invisible, inaudible way without the degradation to thermal comfort commonly caused by draft in HVAC systems.

Capacity at 20 °C room temperature for heating and 26 °C room temperatures for cooling							
Degree Day							
		Exchange Coefficient W/m²K		Surface Temperature °C		W/m²	
		Heating	Cooling	Max. Heating	Min. Cooling	Heating	Cooling
Floor	Perimeter	11	7	35	20	165	42
	Occupied Zone	11	7	29	20	99	42

System	**TABS**	SPECTRA Panel		COMFORT Panel
	Integrated	Gypsum	Metal	Graphite
Investment Cost	**$**	$$	$$$	$$$$
Cooling Capacity	✱	✱✱	✱✱✱	✱✱✱
W/m²	**20-60**	60-70	75-85	>75
Reaction Time	🕒	🕒🕒	🕒🕒🕒	🕒🕒🕒🕒
Installation Time	🕒	🕒🕒	🕒🕒🕒	🕒🕒🕒🕒
Installation Time	**inte-grated into concrete slabs at the beginning of the construction**	Specialist tool required	Specialist tool required	No specialist tool required
Installation Expertise	🔧🔧🔧🔧	🔧🔧	🔧🔧	🔧
Maintenance Cost	**$**	$	$	$

Uponor Spectra (Low Mass)

Spectra ceiling element

The Spectra panels provides better indoor comfort, greater energy efficiency and comfort when compared to All-Air systems. An additional fleece layer on backside of the perforated panel ensures an excellent interior acoustics for a quiet office space. The individual ceiling elements are of the highest quality and are made in an attractive aluminum finish. The reflective ceiling panels also provide a perfect surface for indirect lighting.

Each ceiling panel can be safely connected through a unique magnetic connection below the ceiling. This unique feature makes the installer's job easier, requiring little installation expertise- resulting in speedy installation times.

Spectra gypsum cooling / heating capacity

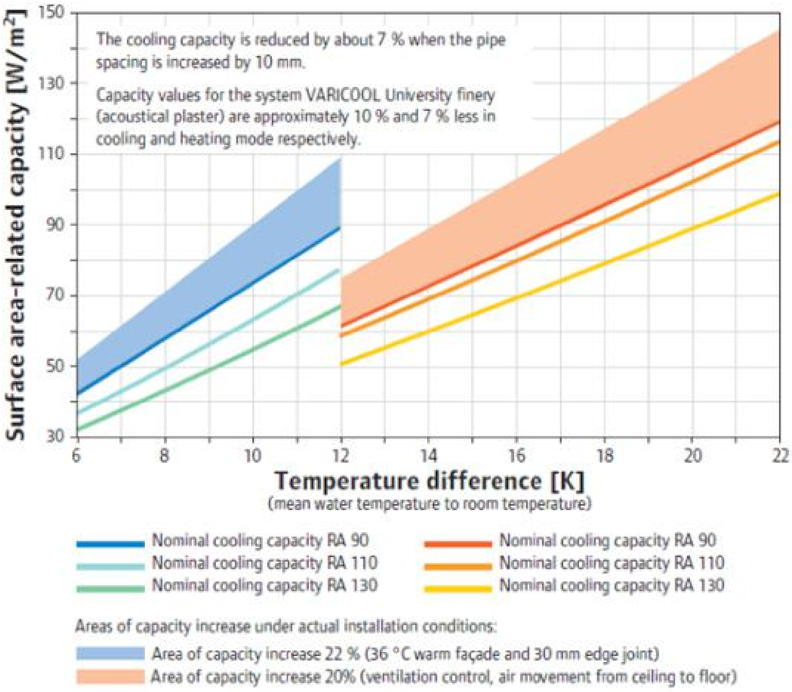
Cooling/heating capacity

The heat transfer in closed, flat chilled ceilings under the test conditions according to EN 14240 (closed test chamber, evenly distributed heat sources, adiabatic boundary surfaces) is characterized largely by radiative heat exchange with the surrounding surfaces and heat sources as well as convection on the bottom side of the cooling ceiling.

The conditions specified in the norm test represent the worst-case scenario. Under practical operating conditions a higher surface area-related cooling capacity is achieved.

The approximate cooling and heating values under standard conditions or realistic installation conditions can be taken from diagram 1. The capacity is read as a function of the temperature difference between the mean water temperature and the room temperature.

Diagram 1:
Heating/cooling capacity system VARICOOL UNI tested according to EN 14240 and EN 14037



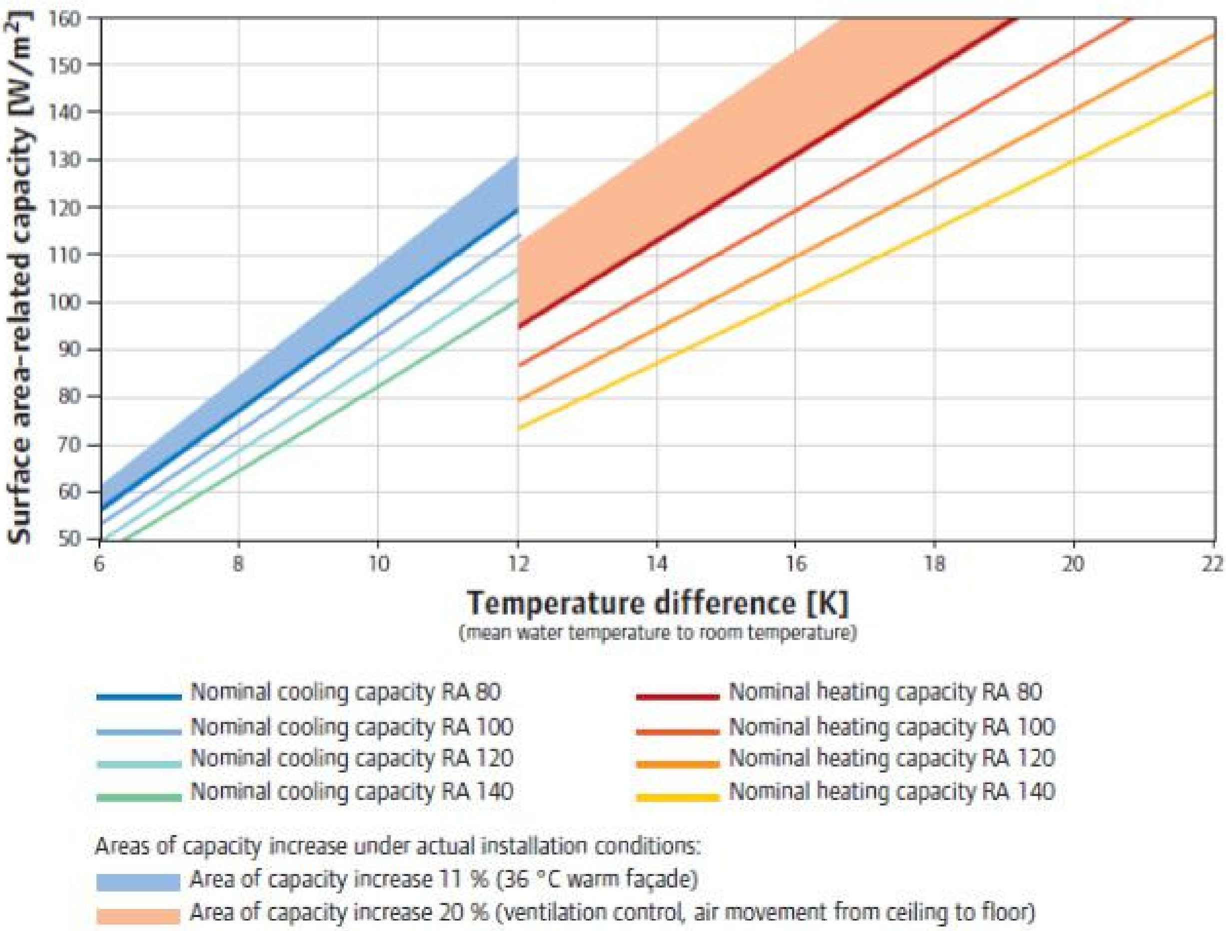
Spectra metal cooling / heating capacity

Planning and dimensioning

Cooling/heating capacity

The approximate cooling and heating values under standard conditions or realistic installation conditions can be taken from the capacity diagram. The capacity is read as a function of the temperature difference between the mean water temperature and the room temperature.

Heating/cooling capacity of system VARICOOL Spectra (version with sheet steel) tested according to EN 14240 and EN 14037



Performance data based on panel coverage of 81%

System	TABS	**SPECTRA Panel**		COMFORT Panel
	Integrated	**Gypsum**	**Metal**	Graphite
Investment Cost	$	**$$**	**$$$**	$$$$
Cooling Capacity	✱	✱✱	✱✱✱	✱✱✱
W/m²	20-60	**60-70**	**75-85**	>75
Reaction Time	🕘	🕘🕘	🕘🕘🕘	🕘🕘🕘🕘
Installation Time	🕘	🕘🕘	🕘🕘🕘	🕘
Installation Time	integrated into concrete slabs at the beginning of the construction	**Specialist tool required**	**Specialist tool required**	No specialist tool required
Installation Expertise	🔧🔧🔧🔧	🔧🔧	🔧🔧	🔧
Maintenance Cost	$	**$**	**$**	$

Uponor Comfort (Low Mass)

Uponor Comfort panel for ceiling cooling and heating

Effective ceiling cooling panel system for commercial buildings

Uponor Comfort Panel is a thermally active ceiling panel for use in suspended ceilings (sub construction) in both new and refurbished buildings. The system can be used for either cooling or heating purposes. The thermally active panels are set into a visible (existing) metal frame substructure and are connected together at the back.

Areas of ceiling not fitted with thermally active panels are finished with visually identical passive panels (blind panels). Depending on the ratio of active to passive ceiling panels, it is possible to achieve a very good level of sound absorption according to EN ISO 354 up to 'highly absorbent' class.

Uponor Comfort panel in a nutshell

- Compatible with existing metal frame constructions
- Better sound absorption than solutions using sound-proof plaster
- Ideal for new offices, renovation projects and new builds in the residential and non-residential sector

Technical features

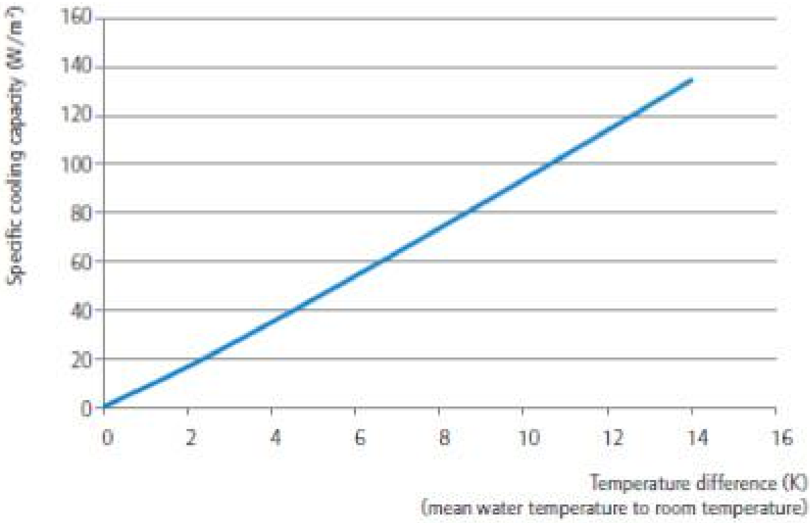
Impressive cooling load of up to 92.5 W/m² at 10 K temperature distance possible

Comfort Panel cooling / heating capacity

Cooling/heating capacity

The approximate cooling and heating capacity in standard conditions can be taken from the diagrams below. The capacity is shown as a function of temperature difference between mean water temperature and room temperature.

It is determined according to EN 14037 for heating output and EN 14240 for cooling output, based on an active area of 86%.



Cooling and heating capacity test conditions:

- Horizontal installation
- Closed ceiling without forced air movement
- Without insulation on the reverse side
- Ceiling height from the floor: 2.5 m

Nominal cooling capacity
($\Delta\theta$=8°C) 74 W/m²

System	TABS	SPECTRA Panel		**COMFORT Panel**
	Integrated	Gypsum	Metal	**Graphite**
Investment Cost	**$**	**$$**	**$$$**	**$$$$**
Cooling Capacity	*	* *	* * *	* * *
W/m²	**20-60**	**60-70**	**75-85**	**>75**
Reaction Time	T	TT	TTT	**TTTT**
Installation Time	T	TT	TT	**T**
Installation Time	integrated into concrete slabs at the beginning of the construction	Specialist tool required	Specialist tool required	**No specialist tool required**
Installation Expertise	🔧🔧🔧🔧	🔧🔧	🔧🔧	🔧
Maintenance Cost	**$**	**$**	**$**	**$**

Uponor - The Radiant Cooling Experts

Uponor is a world leading provider of radiant cooling systems. With thousands of projects in service worldwide, we are the experts at designing an effective, energy-efficient solution for any application.

Experienced Team of Commercial Cooling Specialists

Uponor has an experienced team of dedicated professionals in Asia to assist the engineering and architecture community from concept to commissioning:

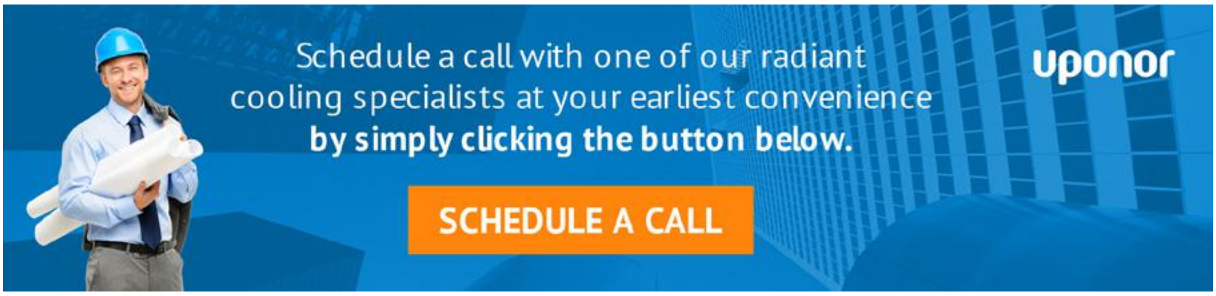
- Commercial sales representatives provide onsite training and education
- Design engineers provide concept and design support
- Project managers provide project coordination from concept to commissioning
- Inside technical support provides CAD drawings, specifications and submittals

How Can an Uponor Air-and-Water Cooling Solution Meet The Cooling Needs of Your Building Project in Asia?

Our specialists are on hand to walk you through just exactly how our radiant cooling solutions can meet the cooling needs of your current or future project.

In our call we will:

- Discuss your project at length
- Identify and analyze possible structural & design challenges
- Answer every question pertaining to our radiant cooling solutions
- Identify the most suitable radiant cooling system for your project



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