i-STUTE Project
- Data Centres

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Aims and progress for data centre project (WP2.3)

Aims

- Firstly, to develop a roadmap of energy efficient data centre cooling technologies
- Secondly, to investigate the potential of a selected new technology for application in data centres

Progress

- Review of current and future data centre cooling technologies
- Preliminary assessment of cooling technologies using a range of evaluation criteria for inclusion in roadmap

Need for new data centre cooling solutions

Key findings from 2012 survey of energy efficiency needs of data centre industry:

(Considered: improving IT efficiency; use of low power processors and hardware; improved efficiency UPS; use of management/control software; and new more energy efficient cooling methods)

1. Only 23% of respondents had implemented new cooling technologies

2. However, new cooling technologies identified by 65% as most likely to offer energy savings

3. Employing new cooling technologies was perceived as difficult to implement

4. 61% of those surveyed highlighted the need for easier identification of energy efficient equipment, and a need for a more objective assessment of power and energy use in data centres

(Source: CDW report, 2012 – Data Centre Solutions That Deliver Energy Efficient IT)

Key issues for data centre owners/operators
(with respect to adopting new cooling technologies)

1. Reliability/resilience/availability
2. Energy and carbon saving %
3. Cost/ROI (payback)
4. Ease of installation (retrofit or new build only)
5. Ease of maintenance

(Based on: data centre industry publications and conversations with industry experts)

Options for improving the energy efficiency of data centres

1. Cooling related:
   - Use of free cooling
   - Use of different cooling technologies

2. IT related:
   - Virtualisation of servers
   - Consolidation of servers
   - Move to cloud

3. Design related:
   - Adoption of modular systems
   - Location to maximize free cooling

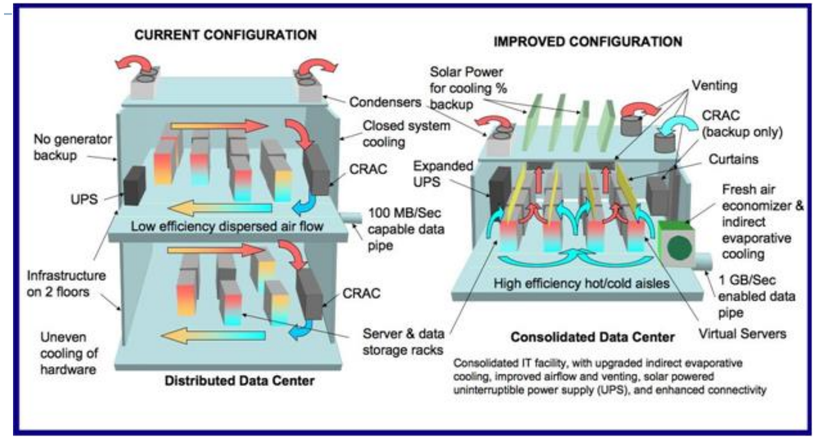
4. Software related:
   - DCIM
   - Predictive modelling
   - CFD

Data centre cooling approaches

Air based

Advantages – Conventional. Effective. Fans, air conditioners and chillers. Electrical compatible. New: free cooling and evaporative cooling, higher operating temperatures

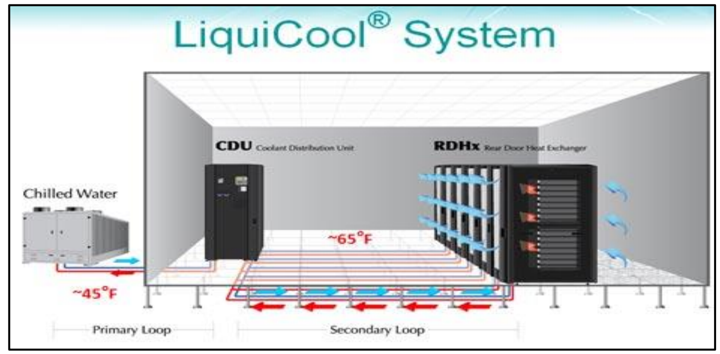
Disadvantages – Low heat carrying capacity, large volumes, costly equipment, inefficient



Water based

Advantages – High heat capacity, pumped, small volumes, efficient, low energy input

Disadvantages – Incompatible with electronics, only recently used in data centres



Refrigerant based

Advantages – Electronics compatible, high heat carrying capacity, particularly 2-phase. Pumped system – low energy input

Disadvantages – not much experience of use in data centres

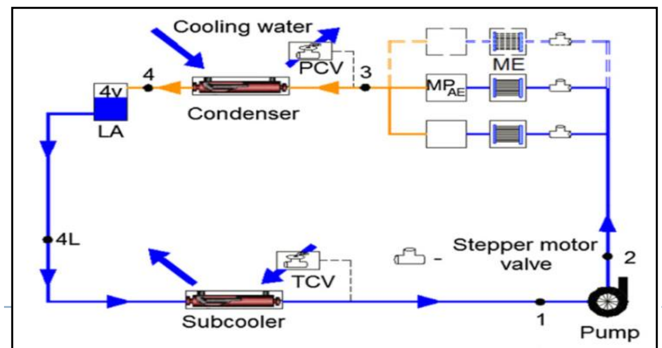


Fig. 3. Schematic of the liquid pump cooling cycle.

Data centre cooling technologies

Air:
(i) Traditional – use of CRACs, CRAHs and chillers around perimeter of room, random layout of racks

Improved efficiency air cooled systems:
(ii) raised floor + hot/cold aisle
(iii) in-row cooling
(iv) contained hot or cold aisle
(v) air side economiser
(vi) direct air free cooling,
(vii) adiabatic free cooling
(viii) direct evaporative
(ix) indirect evaporative
(x) water side economiser

Water:
(i) Direct on-chip water cooling
(ii) Conduction cold plate cooling of server
(iii) Rear door water cooled rack system

Refrigerant:
(i) Immersion cooling of server boards
(ii) Spray cooling of chips
(iii) Direct on-chip 2-phase pumped
(iv) Direct on-chip 2-phase VC system

Future/blue sky:
(i) Thermoelectric
(ii) Thermionic and thermotunnelling
(iii) Thermoacoustic
(iv) Stirling coolers
(v) Air cycle
(vi) Liquid air engine
(vii) Ionic wind
(viii) Porous media

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Evaluation criteria

No.	Main Criteria	Rating
1	Quality of information available	1-5
2	Energy/Emissions savings c.f. baseline case	%
3	PUE	Value
4	Cost savings	%
5	Cost/ROI (payback)	months
6	Reliability/resilience	L/M/H
7	Barriers to take up	L/M/H
8	Availability (to purchase)	L/M/H
9	Commercial maturity	L/M/H
10	Ease of installation	L/M/H
11	Technology independence	L/M/H
12	Maintainability	L/M/H
13	Legislative concerns	L/M/H
14	Scope of application	Retrofit/ New only
	Other Criteria	
15	Capacity	L/M/H
16	Consequences of failure	L/M/H
17	Efficiency of technology	L/M/H
18	Technical maturity of technology	L/M/H
19	Need for further development	L/M/H
20	Time to implement	L/M/H
21	Need for conventional CRAC/chiller backup	Y/N
22	Savings on operating costs c.f. baseline	£
23	Total cost of ownership (TCO)	£

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Comparison/evaluation of cooling technologies 1

Cooling medium	Cooling Technology	Energy saving (%)	PUE	Cost saving.(%)	CO_2 saving (%)	Reliability(L/M/H)	Barriers to uptake (L/M/H)	Availability to purchase(L/M/H)	Limits to commercial maturity(L/M/H)	Ease of use and installation (L/M/H)	Technology independence (L/M/H)	Maintainability (L/M/H)	Legislative issues (L/M/H)	Scope(R/N/B)	Qualification
Air	Inverter driven screw compressor for air cooled chiller	30%-50%	1,55-1.77			H	L	H	L	H	H	H	L	R	Energy saving c.f. compared with non-inverter chiller
	EC fans for condensers	45%	1.61												Energy saving c.f. that for traditional condenser fans
	Fanwall technology		Low	High											
	Humidification e.g. high pressure atomisation or ultrasonic low energy humidifier	93-99%		60%											TCO cost saving on total purchase price and running c.f. traditional steam humidifier
	Direct fresh air-free cooling.	82%	1.2	26%											
	Indirect free cooling	14-55%	1.95 - 1.5												
	Indirect air-to-air free cooling using thermal wheel or plate heat exchangers	96.8%	1.035												PUE achieved depends on the level of redundancy, ambient temperature and operating conditions required
	Direct evaporative cooling (computer room evaporative cooler - CREC)	> 90.9%	< 1.1												PUE indicated is for a N+1 system (Typical PUE 2.1)
	Cooling tower and water cooled chillers	95.9%	1.045												PUE achievable
	Use of borehole at 14°C with water cooled chillers	97.2%	1.03												PUE achievable
	Use of river and sea water with water cooled chillers		v. low	rapid ROI											
	Indirect evaporative modular cooling system (Oasis)	75%	< 1.1	67%											Energy saving c.f. that for a traditional data centre

Comparison/evaluation of cooling technologies 2

Cooling medium	Cooling Technology	Energy saving (%)	PUE	Cost saving c.(%)	CO_2 saving (%)	Reliability(L/M/H)	Barriers to uptake (L/M/H)	Availability to purchase(L/M/H)	Limits to commercial maturity(L/M/H)	Ease of use and installation (L/M/H)	Technology independence (L/M/H)	Maintainability (L/M/H)	Legislative issues (L/M/H)	Scope (R/N/B)	Qualification
Water	Direct on-chip water cooling	80%	1.14	ROI < 1 year											Energy saving c.f. that for a traditional data centre
	In-row cooling	25%	1.82	14%											Energy saving c.f. close control A/C. Reduction in both capital and TCO costs c.f. hot or cold aisle containment.
	Recirculating rack cooling	25%	1.82	7%											Energy saving c.f. close control A/C. Reduction in both capital and TCO costs c.f. hot or cold aisle containment.
	Rear door water cooled heat exchanger	80%	1.22	50%											Energy saving c.f. close control A/C. Reduction in both capital and TCO costs c.f. hot or cold aisle containment. Cooling energy is reduced by > 90%. All sensible cooling.
Dielectric liquid	Immersion cooling of whole server board in dielectric liquid	97.2	1.03												Permits power densities of up to 100 x higher than typical air-cooled servers
Refrigerant	2-phase on-chip cooling - pumped	97.2	1.03												Energy saving c.f. that for a traditional data centre
	2-phase on-chip cooling - vapour compression														Permits discharge of heat at temperatures above ambient

Sources of information for evaluations

- Scientific journal articles, industry articles and published case studies
- Manufacturer information
- Industry seminars and exhibitions
- Input from industry experts/consultants
- Input from data centre operators and designers and cooling equipment manufacturers

Next steps

- Completion of spreadsheet evaluations
- Start writing of roadmap document – coordinate with retail refrigeration roadmap