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An energy efficient use of data centres for ship-pattern analysis

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Abstract

In order to optimising the sea traffic network efficiency, improving the safety of shipping and the protection of the environment, it is useful to model the sea network and its spatio-temporal characteristics of the ship patterns. These maritime patterns could also be an a-priori set of knowledge for the upcoming Maritime Autonomous Surface Ships (MASS) which are starting to navigate our seas with or without remote human controls. The above concepts are crucial and essential elements for defining and understanding the Maritime Situational Awareness (MSA).

Nowadays the applied methodologies for modelling the maritime traffic use large scale of database for extracting the patterns. The Knowledge Discovery from Data (KDD), strictly connected with Data Mining (DM) is growing significantly to modelling the behaviour of the vessels in relations to their surroundings. This is just one example that confirms the growing up of the cloud computing usage for maritime applications too. Besides these applications there are also a continuous and fast evolution of the IT services, which more often than not means data centre scale-ups with consequent improve of power consumptions.

This paper is a case study based on real world data assessing a multi-objective energy consumption analysis. It is based on the comparison between the traditional air conditioning structures known as Heating, Ventilation and Air Conditioning (HVAC) and the Free Cooling Technique (FCT) in order to reduce the data centre power consumption keeping the same number of computational calculations performed.

Keywords: Energy Data centre, Free Cooling, Smart Shipping, Smart Logistics

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1. Introduction

The sea roads are not paved in concrete so the transportation network is a highly dynamic environment that its spatial characteristics can significantly change over time due to many factors like large infrastructure investments, climate change, seasonal effects, traffic regulations enforcements, political events and other international events.

In order to enhancing maritime detection-making and to optimizing the sea traffic network, improving the safety and security, it is necessary to model the sea network and its spatio-temporal characteristics of the ship patterns. These steps are the bases for the Maritime Autonomous Surface Ships (MASS) in which the seaborne vessels can sail in navigable waters with some degrees of remote human controls. The above concepts are crucial and essential elements for defining and understanding the Maritime Situational Awareness (MSA), which represents the effective understanding of activities, events and threats in the maritime ecosystem influencing the global safety and the economic activities (Chatzikokolakis, K., et al., 2021)

Nowadays the Knowledge Discovery from Data (KDD), strictly connected with Data Mining (DM) is growing significantly in order to deploy an accurate network for modelling the behaviour of the vessels and their surroundings, (Chatzikokolakis, K., et al., 2021). All of the applied methodologies for the maritime models use a large scale of datasets for extracting the data, due to the cloud computing is growing up seriously in everyday business activities. Besides the continuous and fast evolution of the IT services, the Data centre scales, the power consumption and the high standard reliability levels are rising suddenly.

In the technologically advanced countries the Data centre are consuming closely 1 to 2.0 percent of the energy produced and its energy consumption is forty times more than a conventional office. (Breen, T. et al., 2010). Furthermore, the main fright of these centres are the energy efficiency followed by availability and security, (Choo, K., et al., 2014). These aspects augment, significantly, the operational cost of running data centres and their related energy balance. As shown in fig. 1 the main sources of energy consumption in a data centre could be grope in to two main categories: the demand-side and the supply-side. The former represents the servers, storages, IT and TLC systems for instance while the latter include all those equipment needed to keep the demand-side running.

Investigating the traditional air conditioning systems, Heating, Ventilation and Air Conditioning (HVAC) the highest equipment power-consumption are the chillers, cooling towers, water pumps, circulation fans and the chiller represents the largest fraction of total energy consumption of HVAC. To conserving the indoor environment, condition the chillers supply the chilled water to the cooling coils to eliminate the heat load of a space.

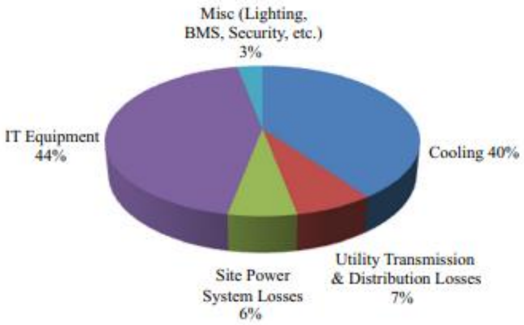

Figure 1: Example of Data center Split

Source: Zhang, H., Shao, S., Xu, H., Zou, H. and Changqing, T. (2014). p.172

The process best known, as direct free cooling met hod is to compare the outside air conditions with t he specified set points, and pulling the outside air directly inside by the airside economizers.

The potential of free cooling represents a measure of the capability of ventilation to ensure indoor comfort without using mechanical cooling systems (Hüsamettin, B., Azmi, M., 2011). The cooler outside air has been utilized by the heat exchangers indirectly by air to air. This process is the simplest technology to be applied to a Data-centre to take out the inside heating. (Lee, K.P., Chen, H.L., 2013). In the latest studies, in Europe the A1-A2 acceptable range (Fig. 2) can be used by the ninety-nine per cent of sites and the airside economizer mode can be used in a large part of the year taking advantage of cooling. On the other hand, in North America the airside economizers can be applied up to 8500 h per year for the seventy-five per cent of data centre (Milnes, D., Schmidt, R., 2014).

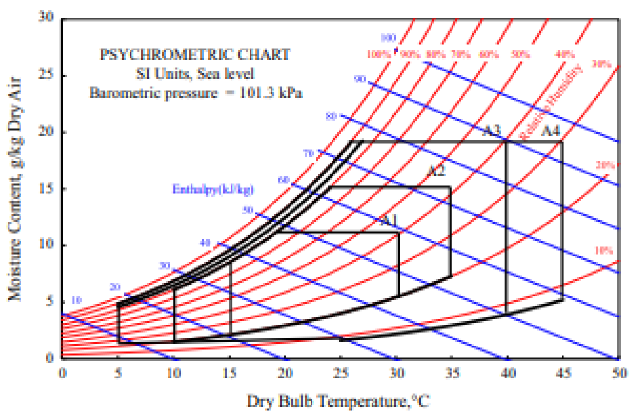

Figure 2: Environmental Classes for Data center-ASHRAE (2011)

Source: De Angelis, F. and Grasselli, U. (2016), p.2

This paper focuses the attention on a multi-objectiv e energy assessment between the traditional Heating, Ventilation and Air Conditioning (HVAC) and the free cooling techniques for optimizing the data cen ter power consumption for Maritime services.

The paper is organised as follows. After the Introd uction, the paragraph two gives an overview of the data center benchmark presented and applied to t hree different sites: Milan Linate, Rome Fiumicino, and Palermo Punta Raisi. Paragraphs 3 and 4 desc ribes the meteorological data used and the. Free C ooling technique applied. They are followed by par agraphs 5 and 6 for the TIER III System approach and the multi-objective energetic analysis. Then co nclusions and references close the paper.

2. Overview

Before starting the energetic evaluation, it is useful to present a data center benchmark. Table 1 sums up the data center room dimensions. Inside the roo m, the racks are 120 (105 active, 15 passive); the t otal of IT load is 584 kW. (De Angelis, F. and Gr asselli, U. 2016)

Table 1-DATA CENTER ROOM Dimension

Dimensions				
Lenght [m]	Width [m]	Height [m]	Area [m^2]	Vol. [m^3]
20	12	4	240	960

Source: De Angelis, F. and Grasselli, U. (2016), p.2

They are organized in Cold and Hot Aisles as shown in fig. 3,

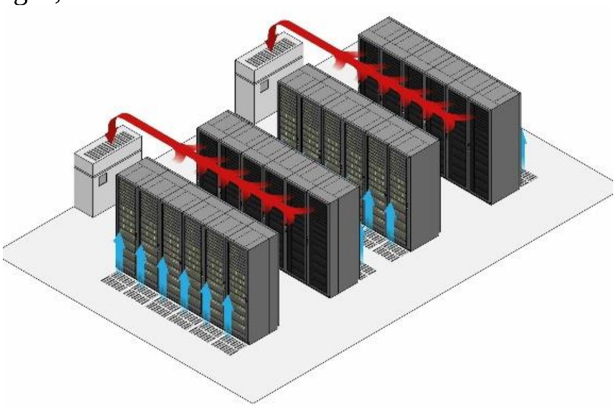

Figure 3: Cold and Hot Aisles

Source: Hot&Cold Aisle scheme (2022)

The indoor cooling plant is composed as exposed in table 2; the total number of Computer Room Air Conditioners (CRAC) are eight but only four active, the rest are in standby mode.

Table 2: Cooling Plant

Outdoor		**Indoor**			
Topology	**Total Cooling [kW]**	**Nr. CRAC**	**Single CRAC-Cooling [kW]**	**Hot Aisle**	**Cold Aisle**
(N+1)	703,37	(4+4)	146	5	4

Source: De Angelis, F. and Grasselli, U. (2016), p.2

During the last decades, the Uptime Institute proposed the Tier Classification in order to compare the groups of sites each other through the functionalities, the capabilities and relative costs of the site infrastructure topologies. (De Angelis, F. and Grasselli, U. (2016), Energy (IYCE), 2015). A summary of the requirements of the four Tier is in table 3. In this paper the data center benchmark is a Tier III architecture.

Table 3: Tier Requirements (Summary)

	TIER			
	I	**II**	**III**	**IV**
Active Capacity	N	N+1	N+1	N after any Failure
Distribution Path	1	1	1Active+ 1 Alternate	2 Simult. Active
Concurrently Maintainable	No	No	Yes	Yes
Fault Tolerant (Single Event)	No	No	No	Yes
Continuous Cooling	Load Density Dependent			Yes(Class A)

Source: De Angelis, F. and Grasselli, U. (2016), p.2

Lastly, about the two main cooling references used in the paper for the multi-objective energetic assessment, in fig.4 the scheme depicts the traditional cooling (HVAC)

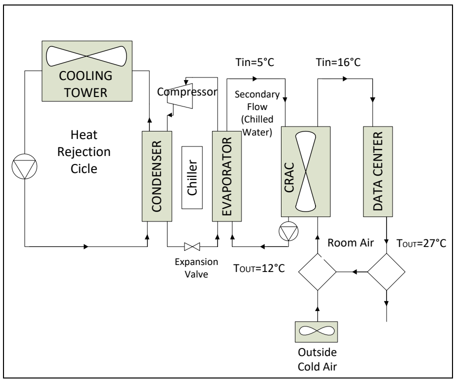

Figure 4: Traditional Cooling Plant

Source: De Angelis, F. and Grasselli, U. (2016), p.3

3. Meteorological Data

The starting point of the multi-objective energetic analysis is the meteorological data. The research survey of the data set required an extensive research. The institutional sites provide only one set of free data but not detailed. (De Angelis, F. and Grasselli, U. 2016)

The searched set of data has the characteristics of being composed by the parameters as dry Temperature (T [°C]), Relative Humidity (UR [%]), Pressure (P[hPa]), Wind direction and intensity [knots] detected hour by hour for 24 hours. This not official type of set has been found in (Meteorological data website, 2016) for the cities of Milan Linate, Rome Fiumicino and Palermo Punta Raisi.

The Italian Military Aviation (Aeronautica Militare, AM) provides only a free set of Meteorological data named CLI NO (CLImate NOrmals) 61-90 (Desiato, F., Fioravanti, G., et al., 2015), which refers to monthly temperatures averages for the years from 1961 to 1990.

After collecting the set for the three cities, the first step is to verify the correlation between the CLINO 61-90 and the not official set (Meteorological data website, 2016). The figures 6, 7 and 8 show the correlation results

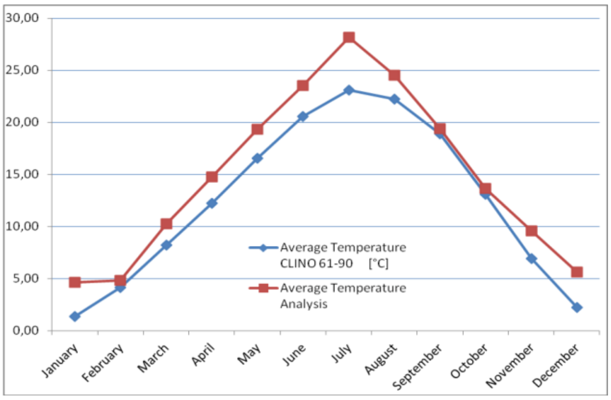

Figure 5: Milan Linate Meteorological Data evaluation

Source: De Angelis, F. and Grasselli, U. (2016), p.3

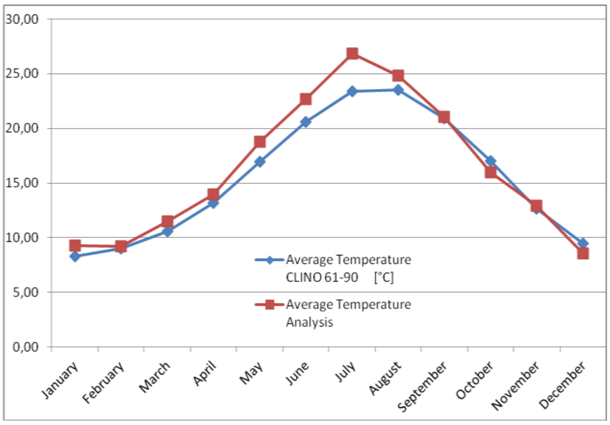

Figure 6: Rome Fiumicino Meteorological Data evaluation

Source: De Angelis, F. and Grasselli, U. (2016), p.3

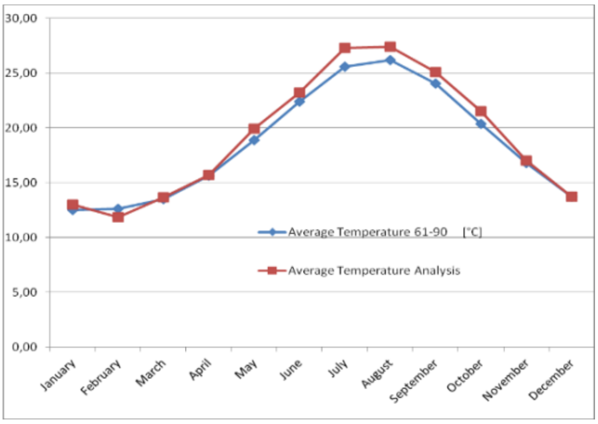

Figure 7: Palermo P.ta Raisi Meteorological Data evaluation

Source: De Angelis, F. and Grasselli, U. (2016), p.3

In table 4 the Pearson correlation index summary among the two sets for the three cities

Table 4: Pearson Correlation Index

Milan-Linate	Rome Fiumicino	Palermo P.ta Raisi
0,987	0,986	0,998

Source: De Angelis, F. and Grasselli, U. (2016), p.3

As shown in the table 4 the not official set has a good index of correlation (near 1) so it is possible to use for the multi-objective energetic analysis. The first use of the meteorological set is to assess each other the external temperatures Text (°C) for the three sites. Due to the large number of data, the analysis has been made using a statistical method. The figure 8 shows the result

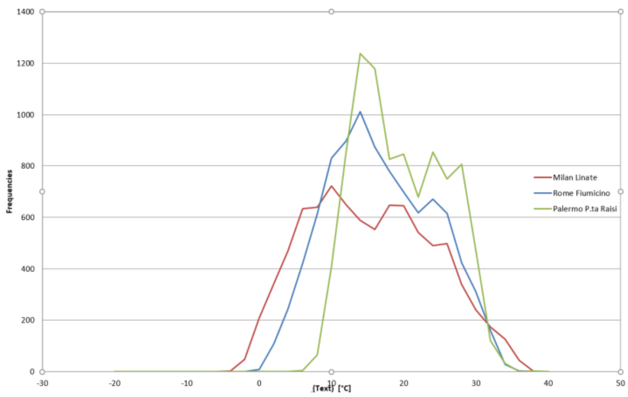

Figure 8: The Text assessment

Source: De Angelis, F. and Grasselli, U. (2016), p.4

4. Free Cooling model

Before presenting the free cooling model, it is necessary to fix the environmental indoor conditions of the data centre.

Table 5: Data Centre Room Environment (T=temperature, DT=Delta of Temperature, UR=Relative Humidity)

T Indoor [°C]	DT Cold-Hot Aisle [°C]	UR [%]

T Indoor [°C]	DT Cold-Hot Aisle [°C]	UR [%]
25	7	55

Source: De Angelis, F. and Grasselli, U. (2016), p.4

The free cooling system utilizes a blower to introduce the outdoor cool air to decrease the cooling load of the data centre, in some measure or completely. A classic air-side is shown in Fig. 10. To turn on the air-side free cooling system it's necessary an enthalpy evaluation as stated by the values of the temperature and relative humidity of the outdoor air (state 05) and return air (state02). The two states are inside the A1 zone. (De Angelis, F. and Grasselli, U., 2016)

Table 6: Free Cooling State (T=temperature, UR=Relative Humidity, h=Enthalphy)

	T [°C]	UR [%]	h [kj/kg]
State 02	25	55	52.9
State 05	18	50	34.3

Source: De Angelis, F. and Grasselli, U. (2016), p.4

The outdoor air has a cooling effect on the data centre in the case of its enthalpy is lower than the return air enthalpy. Furthermore, it is necessary to take in account the costs of humidification or dehumidification if the relative humidity of outdoor air is too low or too high.

In the case study, using the psychrometric chart for the state 02 and the state 05, the difference of enthalpy is 18.6 kJ/kg (Δh>0) as summarized in the table 6.

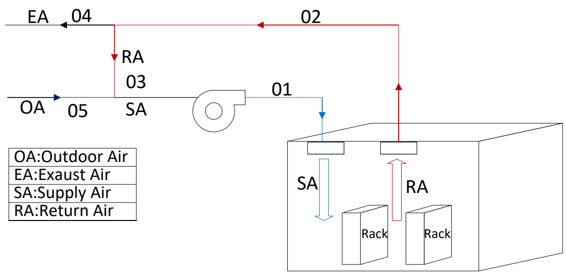

Figure 9: Free cooling system (schema)

Source: De Angelis, F. and Grasselli, U. (2016), p.4

In the case of the relative humidity of the outdoor air is too low or too high, in order to goal the humidity condition standards of the data centre the process of the humidification and dehumidification are required.

Unavoidably the raise of the power consumed by the chiller plant for the humidification equipment is not negligible.

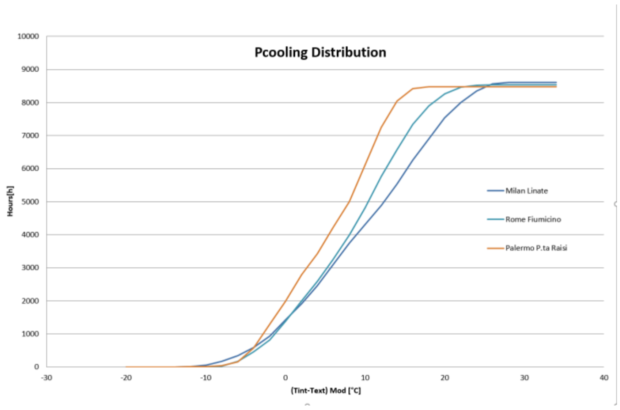

Figure 10: Pcooling distribution

Source: De Angelis, F. and Grasselli, U. (2016), p.4

In figure 10 the use of a statistical method applied to the meteorological set of data provides the three curves which represent the power cooling distribution for the data centre in the three sites. Lastly, the table 7 summarizes the free cooling time of utilization during one year.

Table 7: Free Cooling Utilization

Milan-Linate	*Rome Fiumicino*	*Palermo P.ta Raisi*
61.58%	59.74%	47,92%

Source: De Angelis, F. and Grasselli, U. (2016), p.4

5. Data centre TIER III Model

As introduced in the overview a multi-objective energetic analysis provides also an examination of power infrastructure. The fig.12 shows a typical TIER III arrangement. In this outline during a planned maintenance service, the facility can reach each components in the distribution pathway without influencing any of the IT loads.(De Angelis, F. and Grasselli, U., 2015)

The case of unplanned outages effects significantly on IT loads service and during the maintenance activities, the risk of disruption may be elevated.

In this scheme, the engine generators are the primary power source for data centre and the local power utility can be considered as an economic alternative.

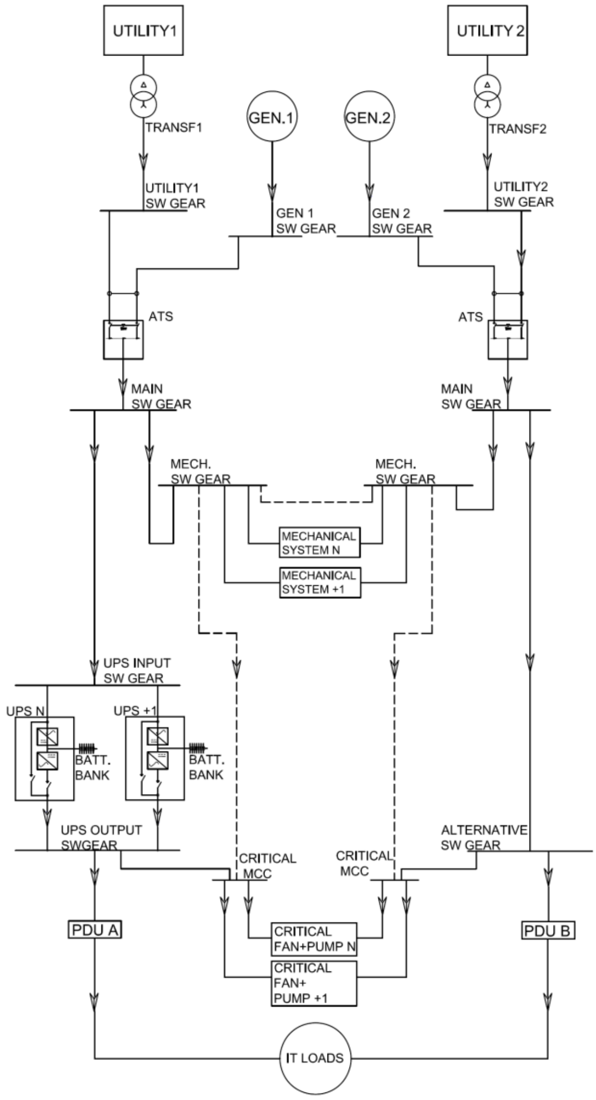

Figure 11: Tier III Scheme

Source: De Angelis, F. and Grasselli, U. (2016), p.6

6. The Energetic Assessment for the free cooling method

For the energetic analysis, the path followed is the use of the Coefficient Of Performance (COP) defined according to Eq. (1):

$$C.O.P. = \left(\frac{Output\ \ Cooling\ \ Energy}{Input\ \ Electrical\ \ nergy}\right) \quad (1)$$

In this case the output Cooling Energy represents the IT load and the Input Electrical Energy is strictly connected to the type of architectures analysed. Using the referring time period of one year (8760h) it's possible to convert Eq. (1) in term of power (De Angelis, F. and Grasselli,U2016):

$$C.O.P. = \left(\frac{PIT}{PCooling}\right) \quad (2)$$

For the two different architectures, it is possible to write the following equations

1. Traditional Cooling with direct free cooling:

$$(C.O.P.)_1 = \frac{PIT}{PCooling1} \quad (3)$$

$$(P)_{Cooling\ \ 1} = ((P)_{Chiller} + (P)_{CCCTw} + (P)_{Pump} + (P)_{Blower} + (P)_{Aux1}) \quad (4)$$

$$(C.O.P.)_2 = \left(\frac{PIT}{PCooling2}\right) \quad (5)$$

2. Only direct free cooling:

$$(P)_{Cooling\ \ 2} = ((P)_{Blower} + (P)_{Aux2}) \quad (6)$$

The term PAUX represents the electrical power used by the auxiliary equipment like the circulation pumps; for the first grade of approximation this term can be quantified as expressed in Eq. 9

$$(P)_{Aux} = (0.05(P)_{Cooling}) \quad (7)$$

For the second level of approximation, the term can be expressed as follow:

$$(P)_{Aux} = \sum_1^n \left[(K)_{P,i}(K)_{u,i}(K)_{n,i}(P)_{n,i}\right] \quad (8)$$

Pn, i= rated power of each component [kW]

Kp, i= load factor of each component

Ku, i= utilization factor of each component [0÷1]

Kc, i= coincidence factor for each component [0÷1]

From the qualitative analysis of the two different architectures (traditional cooling +free cooling and only free cooling) it is possible to write

$$(C.O.P.)_2 > (C.O.P.)_1 \quad (9)$$

$$(P)_{Aux2} < (P)_{Aux1} \quad (10)$$

From the meteorological data set it has been possible to evaluate the behaviour of free cooling for two different air flow rate as shown in figure 12 and 13.The x-axis represents the range of heat to remove from the data centre benchmark; the Y-axis represents the frequencies of the X-axis, occurred, using the set point of table 6.

The behaviour of the free cooling shows its dependence from the mass airflow rate which is strictly connected both to the power consumed by the blower and the location of the site. The figures 12 and 13 show the free cooling performance for the mass airflow rate respectively for two different set of values: (21kg/s, ΔT= 7°C); and (15 kg/s ΔT= 10°C).

For same value of heat transfer, the temperature difference is inversely proportional to the mass flow rate. Besides the diminishing of the airflow, in the case of ΔT= 10°C. The behaviour of the free cooling falls due to the weakening of the less number of frequencies occurred.

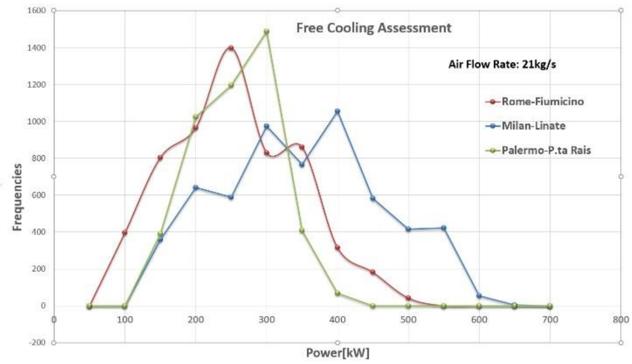

Figure 12: Free Cooling-Air Flow rate 21kg/s-

Source: De Angelis, F. and Grasselli, U. (2016), p.6

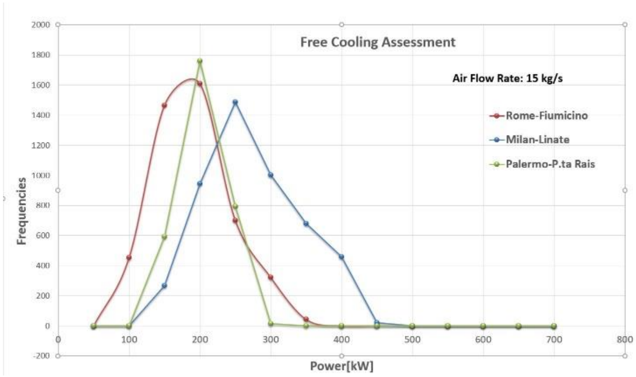

Figure 13: Free Cooling-Air Flow rate 15kg/s

Source: De Angelis, F. and Grasselli, U. (2016), p.6

7. Conclusions

The maritime data centre is becoming a strategic asset for the present and future ports development and ship-pattern analysis. The paper provides a methodology of energy assessment, in term of energy efficient for data centre.

The methodology presented can be applied to different geographical areas. It shows that the free cooling method could be used for a great part of the year. It is therefore necessary to couple this technique with other cooling systems, usually a traditional one. Furthermore, the measurements reported have confirmed the free cooling dependence (i.e. it is function of) from the airflow rate, the temperature range chosen and the geographical location of the site (i.e. external Pressure and temperature at least).

References

Al-Salaymeh A. and Abdelkader M.R.(2011), Efficiency of Free Cooling Technique in Air Refrigeration Systems. (Jordan Journal of Mechanical and Industrial Engineering) Vol.5, No 4, pp. 325 – 333.

Amin, J., Li, H., Zhiqiang, Y., Li, J., Yin, G. and Qinggang, Z. (2011), Experiment Study on Tower Cooling Energy-Saving Technology. Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM), pp 728-730.

ASHRAE Technical Committee (TC 9.9), (2011), Thermal Guidelines for Data Processing Environments Expanded Data and Usage Guidance, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., pp.1-45.

Breen, T., Walsh, E., Punch, J., Shah, A. and Bash, C. (2010), From chip to cooling tower data center modeling: Part I Influence of server inlet temperature and temperature rise across cabinet ,Journal of Electronic Packaging, Vol. 133, pp.1-10.

Chatzikokolakis, K., Zissis, D. Spiliopulos, G. and Vodas M. (2021), A Data-driven methodology for maritime Patterns of Life discovery, ICT Solutions and Digitalisation in Ports and Shipping, IET M.Fiorini, N.Gupta, Ch.8, pp. 253-272.

Choo, K., Manozzo Galante, R., Ohadi, M.M. (2014), Energy consumption analysis of a medium-size primary data center in an academic campus, Energy and Buildings, Vol.76, pp.414-421.

De Angelis, F. and Grasselli, U. (2015), A Data center performance comparison analysis between Tier III architecture and a CCHP alternative solutions. (Energy (IYCE), 2015 5th International Youth Conference), pp 1-6

De Angelis, F. and Grasselli, U. (2016), The next generation green data center: A multi-objective energetic analysis for a traditional and CCHP cooling system assessment, IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), pp. 1-6.

De Angelis, F., Grasselli, U. (2015). The Next Generation Green Data center A Modified Power Usage Effectiveness Metric Proposal for a CCHP Natural gas or Biogas Fuelled Architecture. (2015 IEEE 15th Int.Conf. on Envir. & Electrical Engineering), pp. 1-6.

Desiato, F., Fioravanti, G., Fraschetti, P., Perconti, W. and Piervitali, E., (2015), Valori Climatici Normali di temperature e precipitazioni in Italia, ISPRA (Istituto Superiore per la Protezione e Ricerca Ambientale), pp. 1-63

Fiorini, M., Capata, A. and Bloisi D. (2016), AIS Data Visualization for Maritime Spatial Planning (MSP), International, Journal of e-Navigation and Maritime Economy, Vol.5, pp 45-60.

Ghiaus, C. and Allard, F. (2006), Potential for free cooling by ventilation. (Solar Energy - Solar Energy), Vol.80, pp. 402-

413.

Hot&Cold Aisle scheme: https://www.upsite.com/blog/helping-your-data-center-breath-easier-with-good-air-flow-management/ last access October 2022

Hüsamettin, B., Azmi, M., (2011). Determination of free cooling potential: A case study for İstanbul, Turkey, Applied Energy, Vol.88, pp. 680-689.

Kelley, C., Singh, H., Smith, V., and the Green Grid Technical Committee (2012), Data center Efficiency and It Equipment Reliability At Wider Operating Temperature And Humidity Ranges,White Paper #50, pp 1-37

Lee, K.P., Chen, H.L. (2013). Analysis of energy saving potential of airside free cooling for data centers in worldwide climate zones. (Energy and Buildings), Vol.64. pp. 103–112.

Meteorological data website: http://www.eurometeo.com/english/home; last access August 2016

Milnes, D., Schmidt, R. (2014). Impact of ASHRAE environmental classes on data centers, Thermomechanical Phenomena in Electronic Systems -Proceedings of the Intersociety Conference, pp.1092-1099.

Phu, D. Q. and Tho, D. T. (2014), A study of energy effectiveness in a cooling tower, 2014 International Conference and Utility Exhibition on Green Energy for Sustainable Development (ICUE), pp. 1-6.

Vertiv, (2017) Focused Cooling Using Cold Aisle Containment, White Paper, Vertiv, pp 1-16

Wu, D. and Wang, R.Z. (2006). Combined cooling, heating and power: A review, (Progress in Energy and Combustion Science), Vol. 32, pp.459-495.

Zhang, H., Shao, S., Xu, H., Zou, H. and Changqing, T. (2014). Free cooling of data centers: A review. Renewable and Sustainable Energy Reviews, Vol.35.pp.171–182.

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