

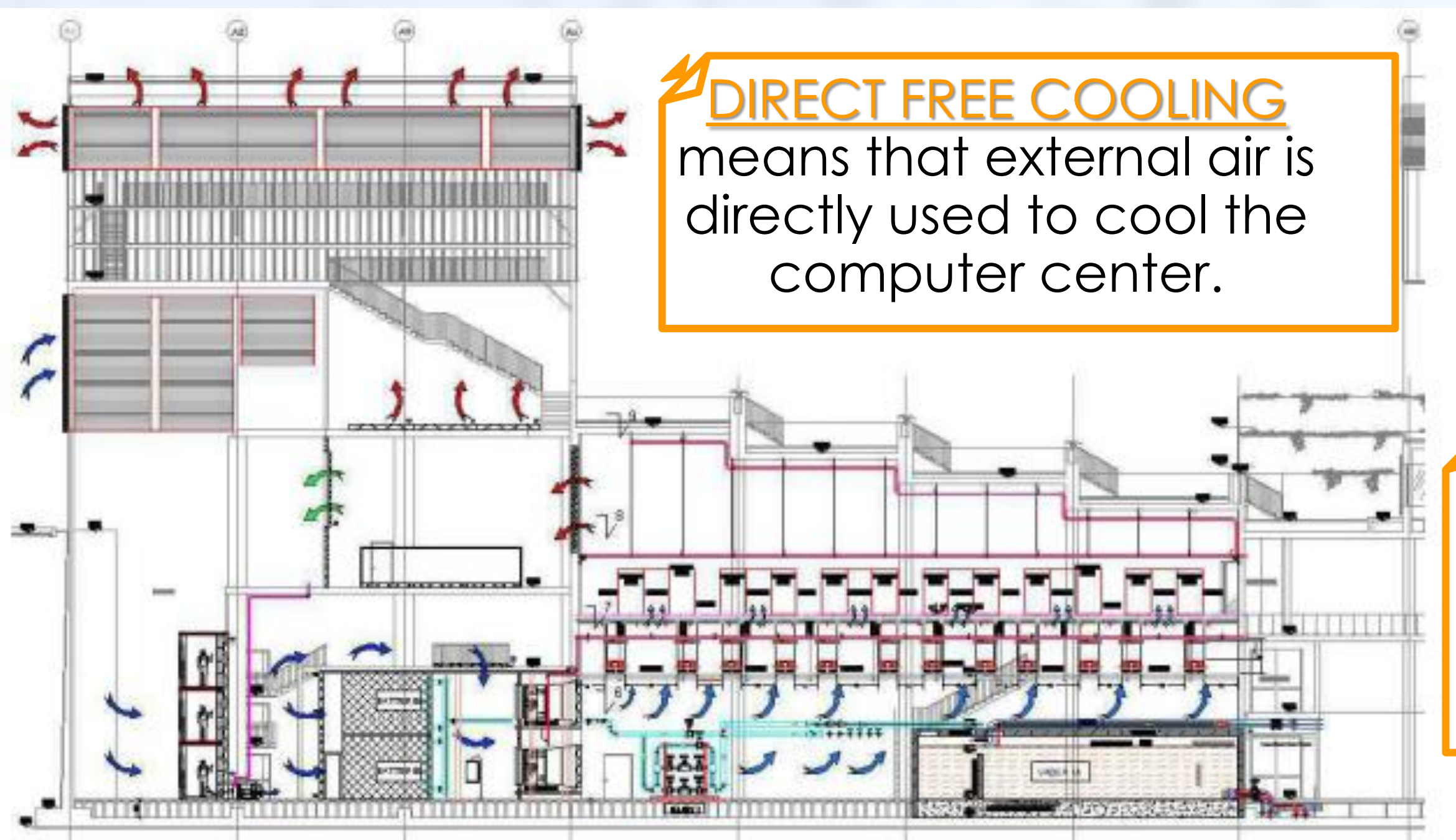
PM_{2.5}, PM₁ and PM_{0.4} hygroscopicity during spring and summer at one Po Valley site Application to the desining of a computer center

L. Ferrero¹, G. Sangiorgi¹, M.G. Perrone¹ and E. Bolzacchini¹

¹POLARIS Research Centre, Department of Environmental Sciences, University of Milan - Bicocca, Milan, I-20126, Italy
contact author: luca.ferrero@unimib.it

✓ **OBJECT OF THE STUDY: DATA CENTER (5200 m² of computers) characterized by a DIRECT FREE COOLING DESIGN**

Energy saving depends on external climatic conditions but it can reach values as high as ~50% compared to other cooling techniques (indirect or using common conditioning systems)



DIRECT FREE COOLING means that external air is directly used to cool the computer center.

BUT...

...**Aerosol** that comes into the computer center during the **DIRECT FREE COOLING can damage** the computers due to their:

- **Chemical effects** (corrosion...)
- **Mechanical effect** (prevented the dissipation of heat...)
- **Electrical effects** (arc effect...)

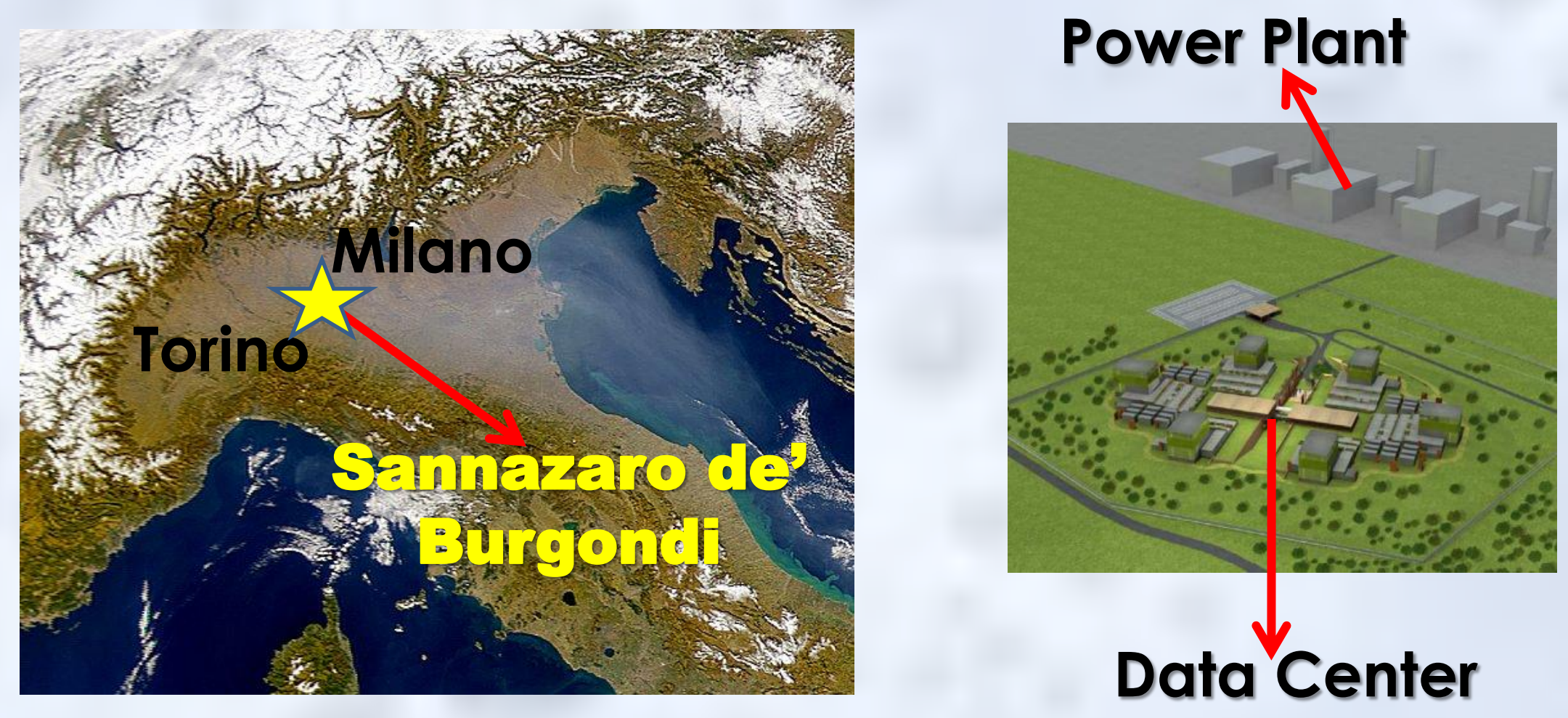
THUS... international technical committee (**ASHRAE**) have given the limits on: **aerosol number concentration** (in function of size: **ISO8 standard**), **temperature** (15-32°C) and **relative humidity** (20-80%) to prevent aerosol contamination and **aerosol hygroscopicity**... thermodynamic limits have to be adapted to the aerosol hygroscopic properties of the air entering in the system.



ISO CLASS	Maximum Number of Particles in Air (particles in each cubic meter equal to or greater than the specified size)				
	> 0.1 µm	> 0.2 µm	> 0.3 µm	> 0.5 µm	> 1 µm
Class 1	10	2	1	0.5	0.1
Class 2	100	24	10	4	1
Class 3	1000	237	102	35	8
Class 4	10,000	2,370	1,020	352	83
Class 5	100,000	23,700	10,200	3,520	832
Class 6	1,000,000	237,000	102,000	35,200	8,320
Class 7	10,000,000	2,370,000	1,020,000	352,000	83,200
Class 8	100,000,000	23,700,000	10,200,000	3,520,000	832,000
Class 9	1,000,000,000	237,000,000	102,000,000	35,200,000	8,320,000

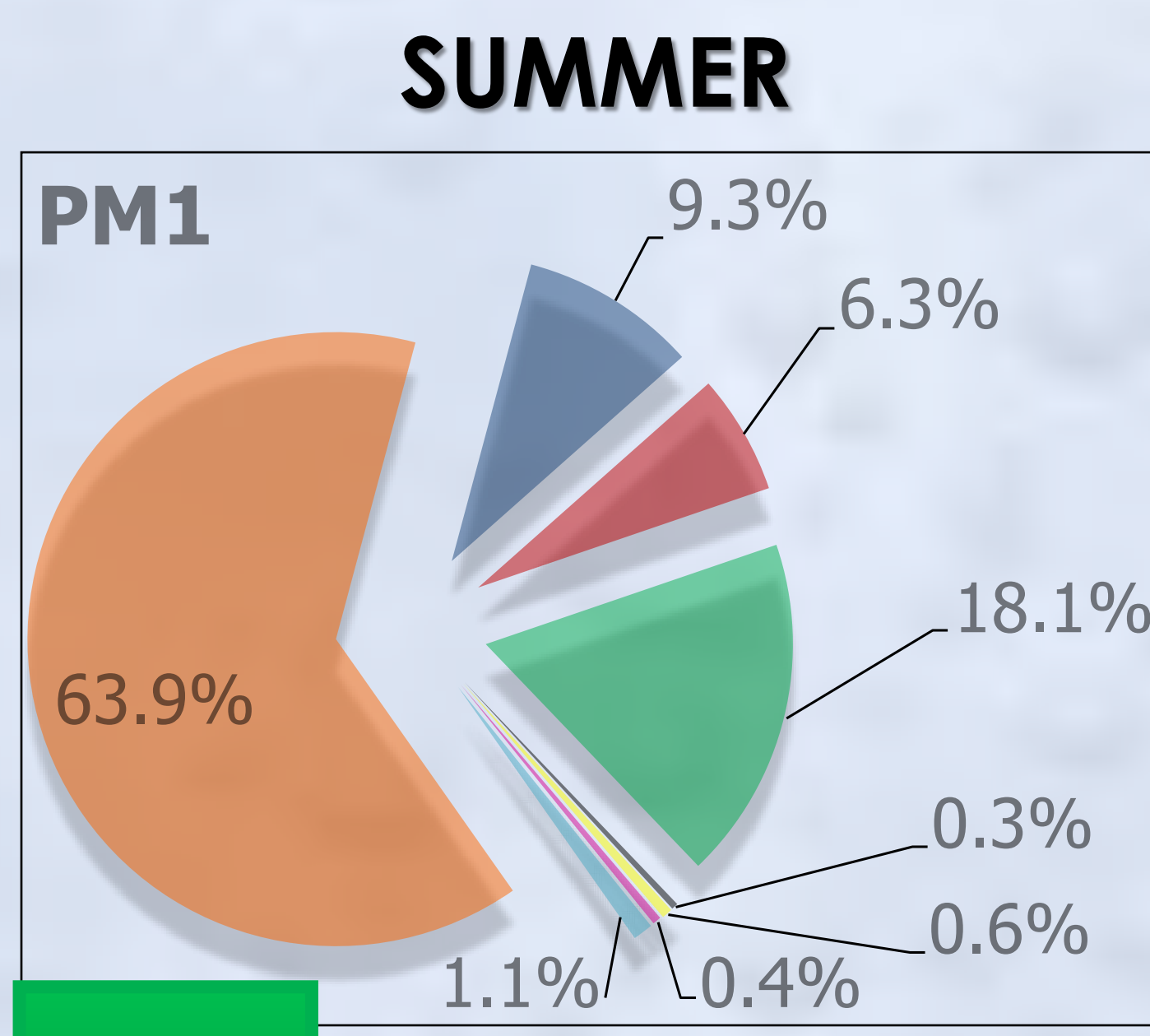
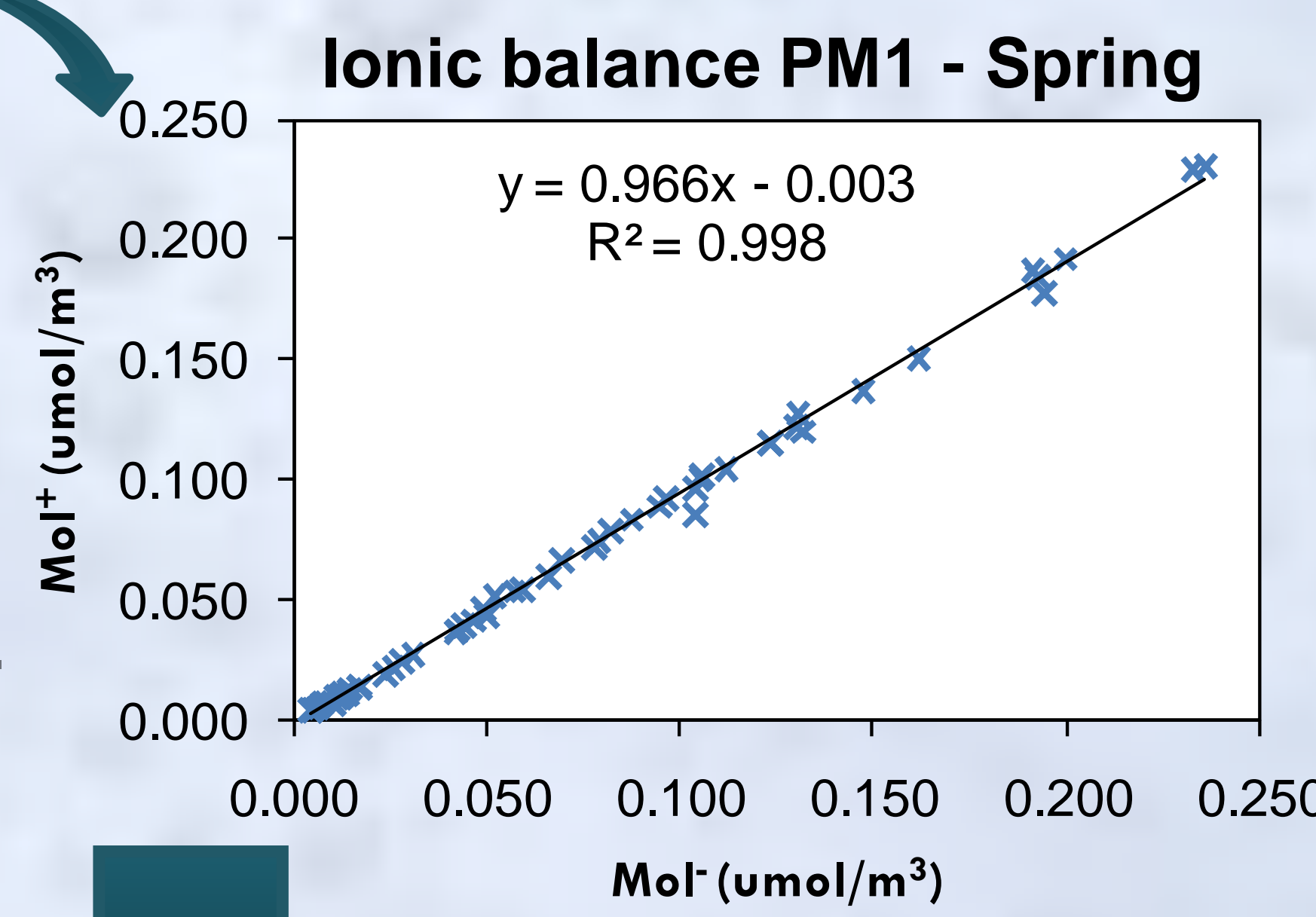
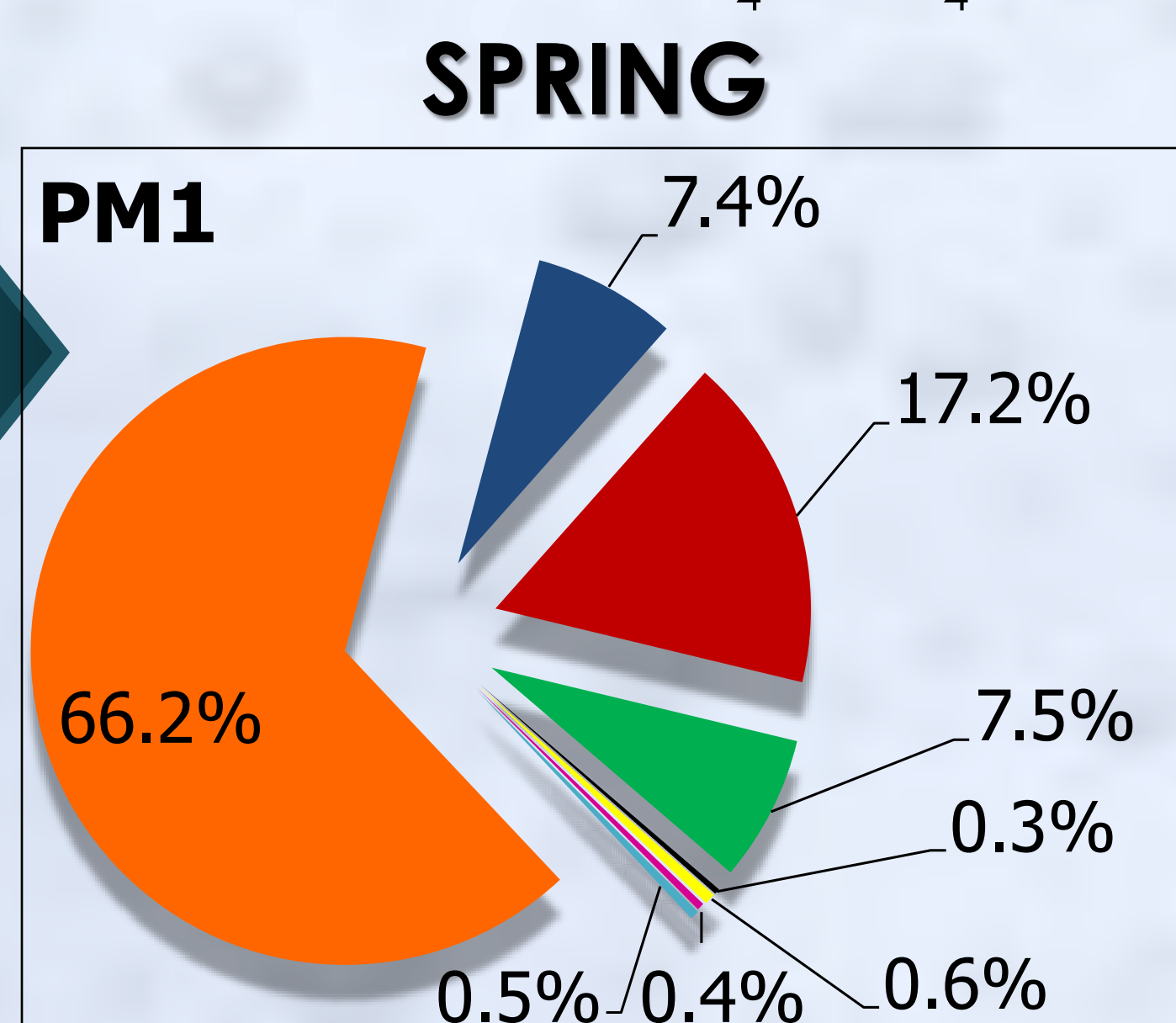
✓ **SAMPLING SITE: SANNAZARO DE' BURGONDI (PAVIA) in the middle of the Po Valley, Italy near one of the largest power-plants of Italy**

✓ **ANALYSIS:** PTFE filters extracted in ultra-pure water by ultrasonic bath and analyzed by IC (Dionex® ICS90 and ICS2000 coupled system).



water soluble inorganic ions
Na⁺, NH₄⁺, K⁺, Mg²⁺, Ca²⁺, F⁻, Cl⁻, NO₃⁻, PO₄³⁻, SO₄²⁻

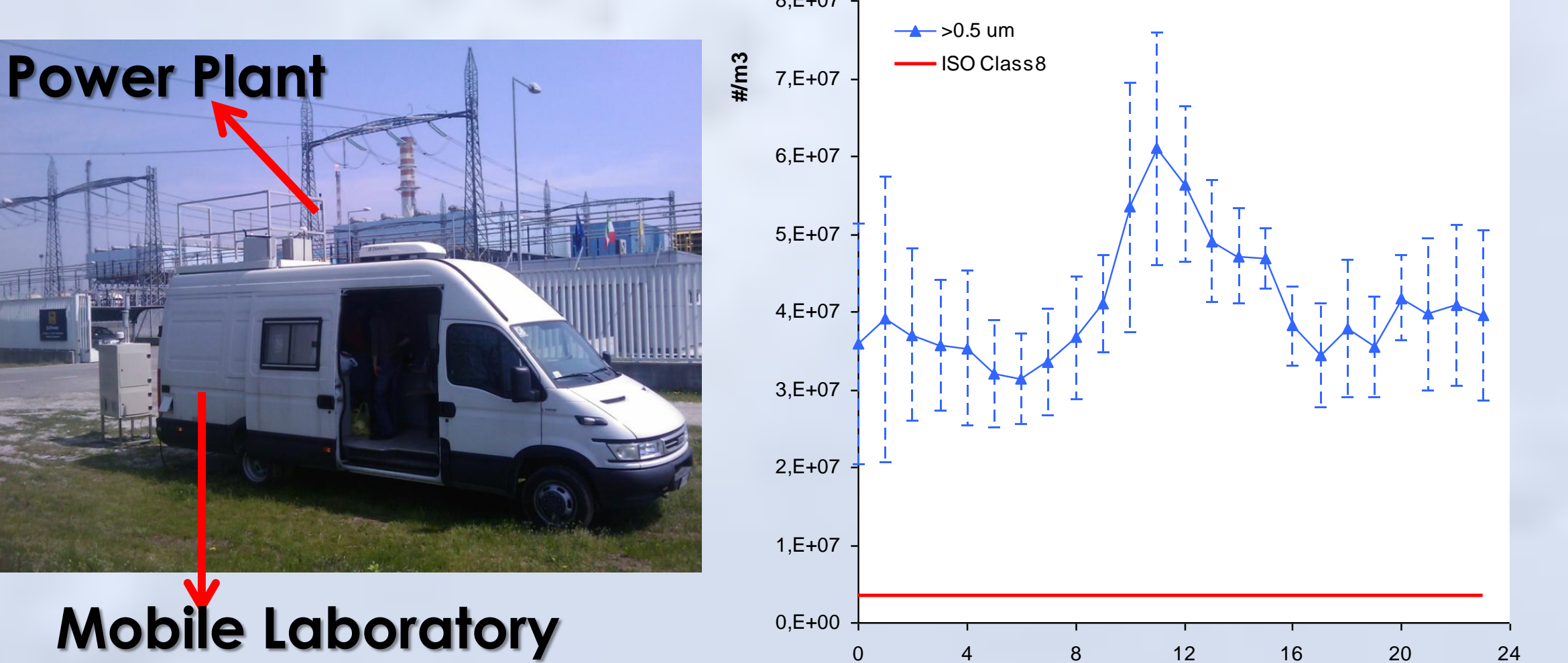
mono-/dicarboxylic acids
acetic, propionic, formic, glutaric, succinic, malonic, maleic, oxalic acids



Very similar pattern of ionic balance for both the seasons and all the PM_x: **R² very high (R² ≥ 0.96)**; slope very close to 1 (**slope ≥ 0.85**). The neutrality condition of aerosol prevent the computer damage due to acidity. However is very important to assess the aerosol hygroscopicity to prevent any corrosion problem due to the overcoming of the Mutual Deliquescence Relative Humidity (MDRH) of aerosol.

✓ **SAMPLING CAMPAIGN: PM_{0.4} + PM₁ + PM_{2.5} + OPC-Tandem System (OPC_{dry}+OPC_{wet}) + Meteo Parameters**

SPRING: 10 June – 2 July 2010; **SUMMER:** 24 March – 29 April 2010

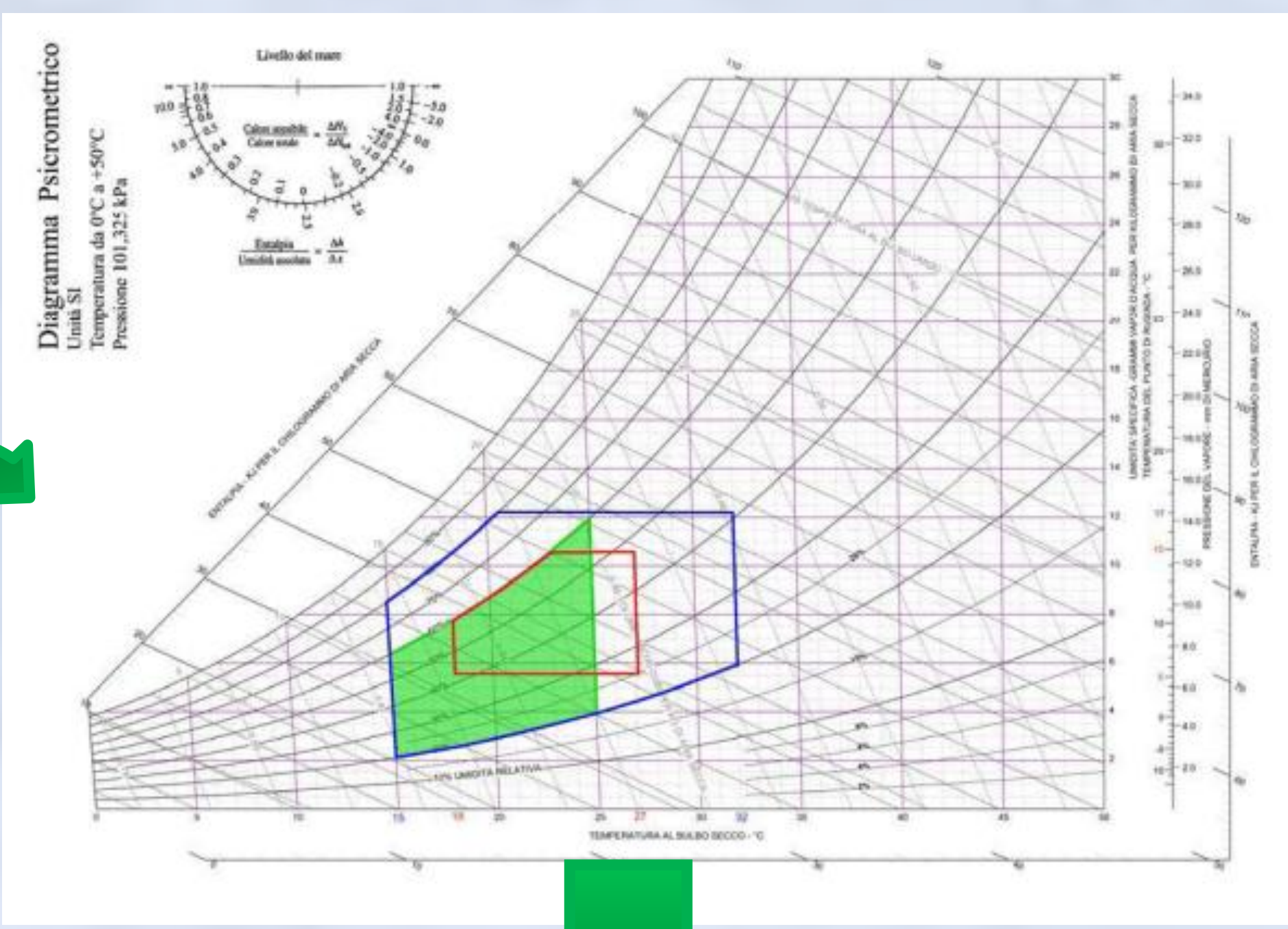


High Pollution levels (aerosol concentrations above ISO8 standards) need for an **aerosol chemico-physical characterization...**

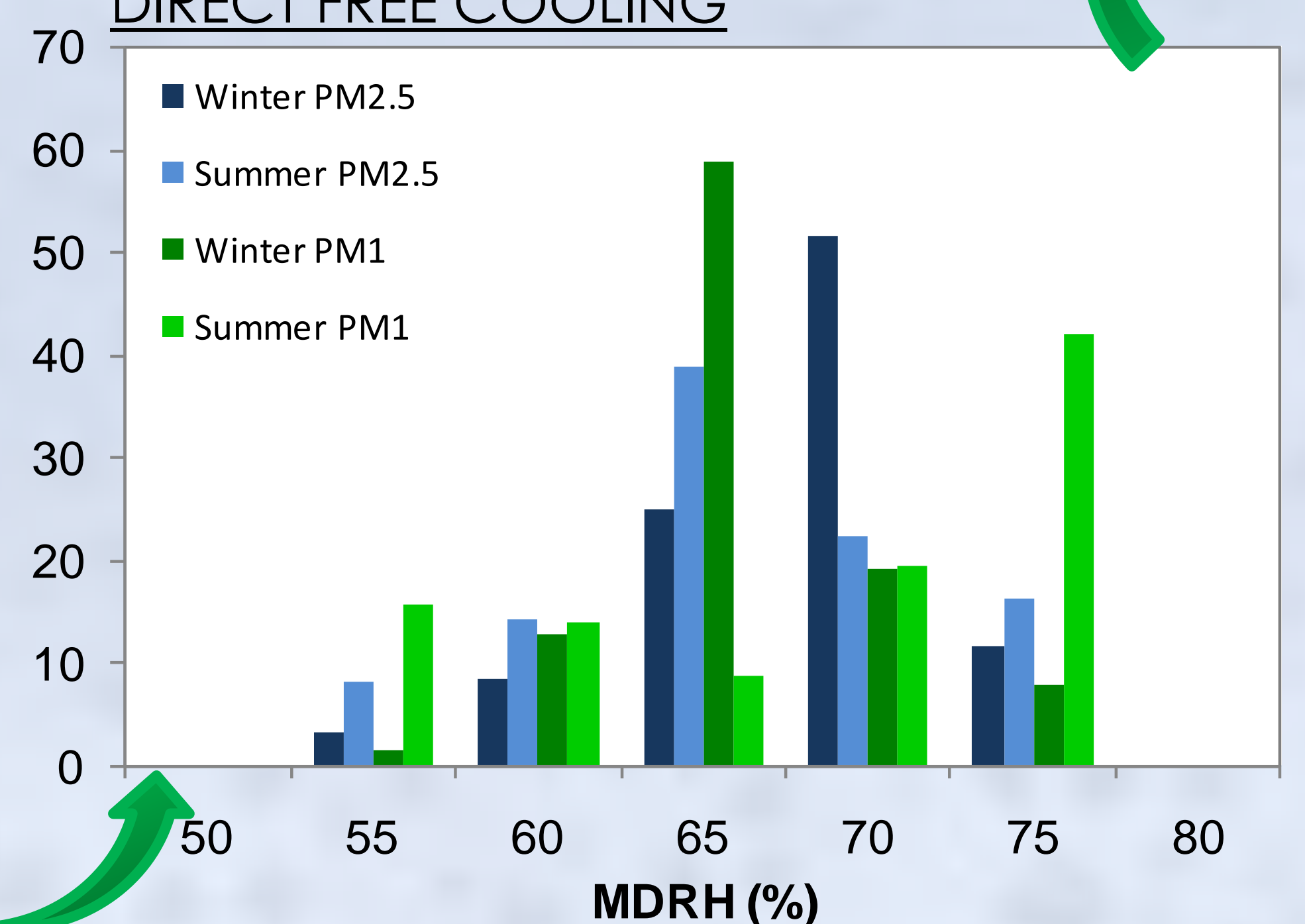
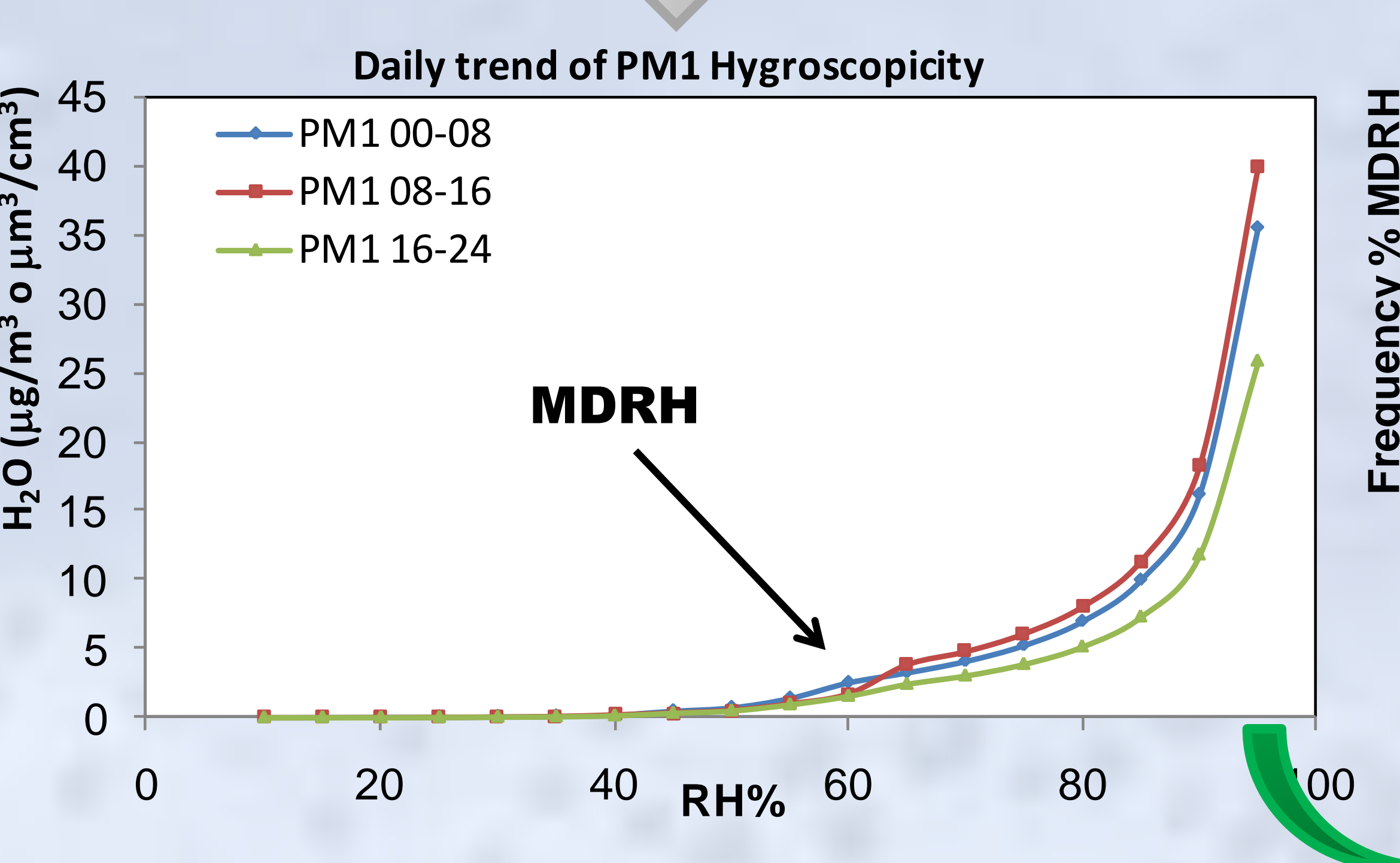
✓ **AEROSOL HYGROSCOPICITY:** Aerosol Inorganic Model (E-AIM), an aerosol thermodynamic model that can simulate aerosol water content, free acidity (free H⁺), and activities of ionic species in aqueous aerosols and the solid- and liquid-phase compositions (Clegg et al., 1998; <http://www.aim.env.uea.ac.uk/aim/aim.php>)

	SPRING		SUMMER	
	T (°C)	RH %	T (°C)	RH %
PM _{2.5}	12±5	72±19	21±5	72±17
PM ₁	12±4	72±18	23±5	69±15
PM _{0.4}	12±1	77±9	26±1	61±3

Frequency distribution of MDRH + external air thermodynamic condition allow to find the best thermodynamic range (the green one in the psychrometric table) to use the **DIRECT FREE COOLING**



AEROSOL CHEMISTRY + THERMODYNAMIC CONDITIONS



CONCLUSION
The study of **aerosol Hygroscopicity** coupled with aerosol concentration and thermodynamic studies allowed to find the best conditions to use a **DIRECT FREE COOLING** in a computer center. This approach allowed to design a **cooling system able to save up to 60% of energy** compared to classical conditioning systems.