Africa-Europe Bioclimatic Collaboration 21

Africa-Europe BioClimatic buildings for XXI century

Key performance indicators

POLITECNICO MILANO

eERG

end-use Efficiency Research Group

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Silvia Erba
Politecnico di Milano - DAStU
silvia.erba@polimi.it

Lorenzo Pagliano
Politecnico di Milano - DAStU
lorenzo.pagliano@polimi.it

ABC 21 project has received funding from the EU's Horizon 2020 research and innovation programme under Grant Agreement No. 894712.

Research Problem and Objectives

RESEARCH PROBLEM AND QUESTIONS

- Widespread adoption of **inadequate design solutions** and **construction practices**
- Gap in **measured data** of thermal comfort parameters, especially from African buildings
- How bioclimatic buildings behave **today** and under **future weather scenarios**?

OBJECTIVES

- Identify **existing** case studies of **bioclimatic buildings** in warm climates
- Verify the **buildings' performance on site** by measuring environmental parameters and collecting occupants' feedback
- Evaluate the buildings' performance using **future weather files** created for warm climates
- Point out building **strengths and weaknesses** as input for technical guidelines
- **Disseminate** exemplary case studies and well-performing strategies

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Process

ABC 21

1. Identification of **Key Performance Indicators** for bioclimatic buildings, used both for assessments based on measured and simulated data

2. Selection of **24 case studies** of European and African bioclimatic buildings

3. Characterization of the **building's performance** through KPIs and identification of **missing data**

4. Definition of a **monitoring plan** in some of the selected buildings and **installation** in the pilot buildings

5. Monitored **data acquisition** and collection of **Post Occupancy Evaluations** in the buildings

6. Analysis of the data

7. Input for technical guidelines

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1. Key Performance Indicators

OBJECTIVES:

- to **quantify** and **benchmark** building performance for assessing any potential savings along with evaluating and validating improvements
- to **planning**, **design**, construction, and commissioning > in new constructions
- to perform fault detection and diagnostics, **measurement and verification**, along with making retrofit decisions > in existing buildings
- to assess **impacts** before and after the implementation of a certain strategy on different domains (e.g., energy, indoor environmental quality) and thus to determine the success of the project in reaching its objectives
- to simplify complex information

HOW:

- using data measured in the buildings
- using data obtained from calibrated energy simulations

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A common language

ISO 52000 - A set of terms and definitions

English Version

Energy performance of buildings - Overarching EPB assessment - Part 1: General framework and procedures (ISO 52000-1:2017)

Performance énergétique des bâtiments - Évaluation cadre PEB - Partie 1: Cadre général et modes opératoires (ISO 52000-1:2017)

Energieeffizienz von Gebäuden - Festlegungen zur Bewertung der Energieeffizienz von Gebäuden - Teil 1: Allgemeiner Rahmen und Verfahren (ISO 52000-1:2017)

Also available on the ISO platform (Online Building Platform), in English and in French

Terms & Definitions

energy need for heating or cooling

heat to be delivered to or extracted from a thermally conditioned space to maintain the intended space temperature conditions during a given period of time

ISO 52000-1:2017(en), 3.4.13

besoin d'énergie pour le chauffage ou le refroidissement

chaleur à fournir ou à extraire d'un espace climatisé pour maintenir les conditions de température voulues dans cet espace pendant une durée donnée

ISO 52000-1:2017(fr), 3.4.13

Available in: EN FR

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A common language

EN 16798

English Version

Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6

Performance énergétique des bâtiments - Ventilation des bâtiments - Partie 1 : Données d'entrées d'ambiance intérieure pour la conception et l'évaluation de la performance énergétique des bâtiments couvrant la qualité de l'air intérieur, l'ambiance thermique, l'éclairage et l'acoustique (Module M1-6)

Energetische Bewertung von Gebäuden - Teil 1: Eingangsparameter für das Innenraumklima zur Auslegung und Bewertung der Energieeffizienz von Gebäuden bezüglich Raumluftqualität, Temperatur, Licht und Akustik - Module M1-6

ASHRAE 55

ANSI/ASHRAE Standard 55-2020
(Supersedes ANSI/ASHRAE Standard 55-2017)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

ISO 7730

INTERNATIONAL STANDARD **ISO 7730:2005(E)**

Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

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Key Performance Indicators

See reports on indicators on abc21.eu	
ENERGY PERFORMANCE	1. Energy need for heating
	2. Energy need for cooling
	3. Energy use for lighting
	4. Energy need for domestic hot water
	5. Total primary energy use
	6. Renewable primary energy generated on-site
	7. Renewable primary energy generated on-site and Self consumed
	8. Renewable primary energy exported to the grid
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation)
	10. Delivered energy (from electricity bills)
THERMAL COMFORT	1. Percentage of time outside an operative temperature range (Adaptive)
	2. Percentage of time outside an operative temperature range (Fanger)
	3. Degree-hours (Adaptive)
	4. Degree-hours (Fanger)
	5. Percentage of time inside the Givoni comfort zone (1 m/s)
	6. Percentage of time inside the Givoni comfort zone (0 m/s)
	7. Number of hours within a certain temperature range
VISUAL COMFORT	1. Light level (illuminance)
	2. Daylight
	3. Glare control
	4. Quality view
	5. Zoning control
ACOUSTIC COMFORT	1. Airborne sound insulation
	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
INDOOR AIR QUALITY	1. Organic compound
	2. VOCs
	3. Inorganic gases
	4. Particulates (filtration)
	5. Minimum outdoor air provision
	6. Moisture (humidity, leaks)
	7. Hazard material

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Thermal comfort

ISO 7730

“Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment”

ASHRAE 55:2020

“Thermal comfort is that condition of mind that expresses **satisfaction** with the thermal environment **and is assessed by subjective evaluation**.”

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Thermal comfort

Rational Models

- Developed by Fanger
- Derived by analyzing surveys carried out on large samples of people exposed to **steady-state conditions** in **controlled climate chambers**
- and by modeling the heat balance of the human body using a steady-state heat transfer model
- application in heated and/or mechanical cooled buildings

Adaptive Models

- Derived from the statistical analysis of data from field studies of people in real buildings (e.g. de Dear, Brager, Cooper and Nicol and McCartney)
- the neutral temperatures are mostly linked to the **outdoor temperatures**, rather than to the indoor conditions as assumed by the rational model
- application in naturally ventilated buildings and to buildings that have a mechanical cooling system installed, as long as the system is not running

Bioclimatic charts

- simple tools to analyze climate conditions and investigate appropriate design recommendations for different climates (Olgyay Bioclimatic chart, the Szokolay Bioclimatic chart, the Givoni-Milne chart and the Mahoney Table)
- To quantify the climate severity and the thermal comfort levels inside the building, to understand the way the building has to be designed to obtain a comfortable thermal sensation for the users

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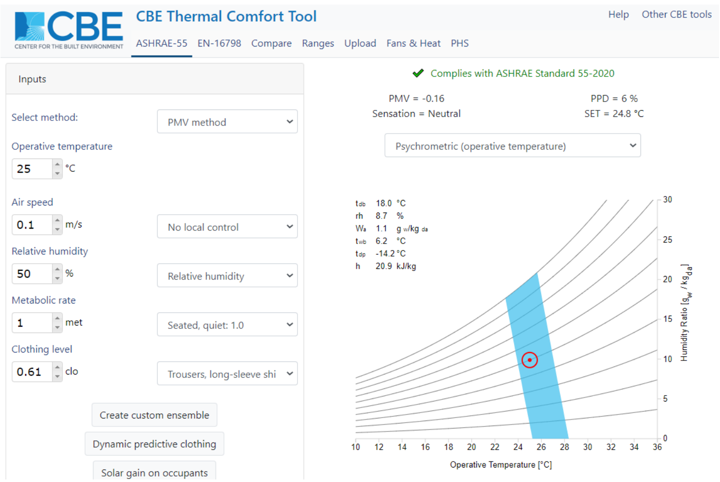
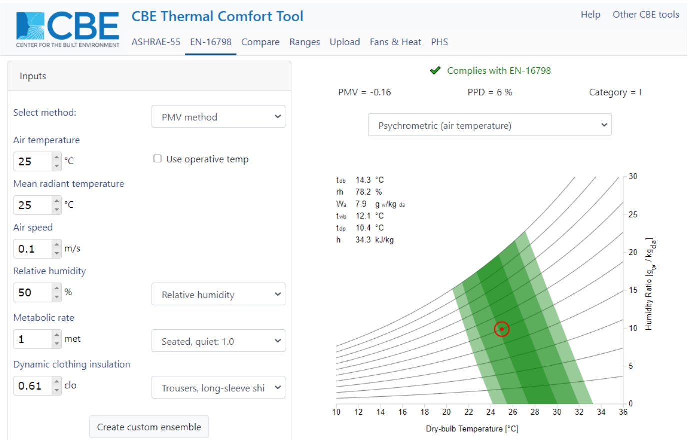
Operative temperature

It is the uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by **radiation** plus **convection** as in the existing non-uniform environment (EN ISO 7726:2001)

$$t_o = \frac{h_c \cdot t_a + \bar{h}_r \cdot \bar{t}_r}{h_c + h_r}$$

t_a	is the air temperature;	°C
$\bar{t}_r$	is the mean radiant temperature;	°C
h_c	is the heat-transfer coefficient by convection;	W/(m²K)
h_r	is the heat-transfer coefficient by radiation.	W/(m²K)





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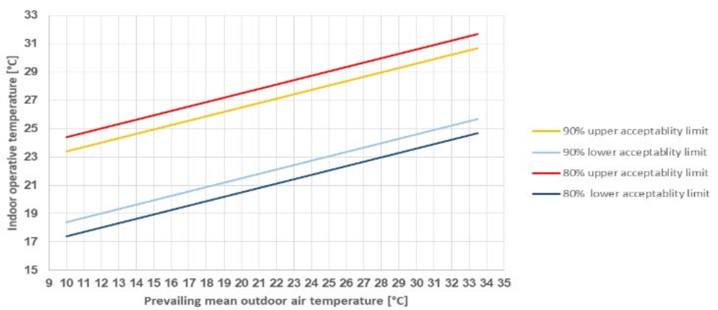
Thermal comfort indicator

- Percentage of time outside an operative temperature range (Adaptive)
- Percentage of time outside an operative temperature range (Fanger)
- Degree-hours (Adaptive)
- Degree-hours (Fanger)
- Percentage of time inside the Givoni comfort zone (1 m/s)
- Percentage of time inside the Givoni comfort zone (0 m/s)
- Number of hours within a certain temperature range

Def: *"Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range calculated according to the* ***adaptive thermal comfort model****"*

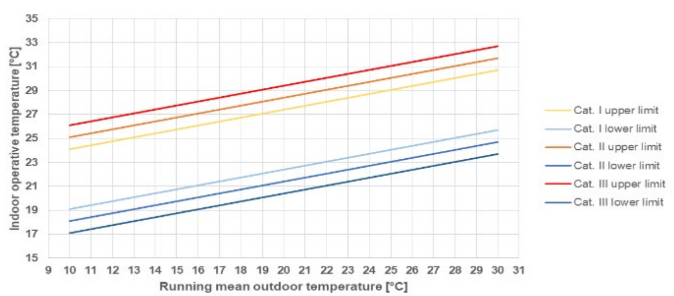
Class	Limit	Operative Temperature
90%	Upper	$T_o = 0.31*t_{pma(out)} + 17.8 + 2.5$
	Lower	$T_o = 0.31*t_{pma(out)} + 17.8 - 2.5$
80%	Upper	$T_o = 0.31*t_{pma(out)} + 17.8 + 3.5$
	Lower	$T_o = 0.31*t_{pma(out)} + 17.8 - 3.5$

ASHRAE 55:2020



Class	Limit	Operative Temperature
I	Upper	$T_o = 0.33*T_{rm} + 18.8 + 2$
	Lower	$T_o = 0.33*T_{rm} + 18.8 - 3$
II	Upper	$T_o = 0.33*T_{rm} + 18.8 + 3$
	Lower	$T_o = 0.33*T_{rm} + 18.8 - 4$
III	Upper	$T_o = 0.33*T_{rm} + 18.8 + 4$
	Lower	$T_o = 0.33*T_{rm} + 18.8 - 5$

EN 16798:2019



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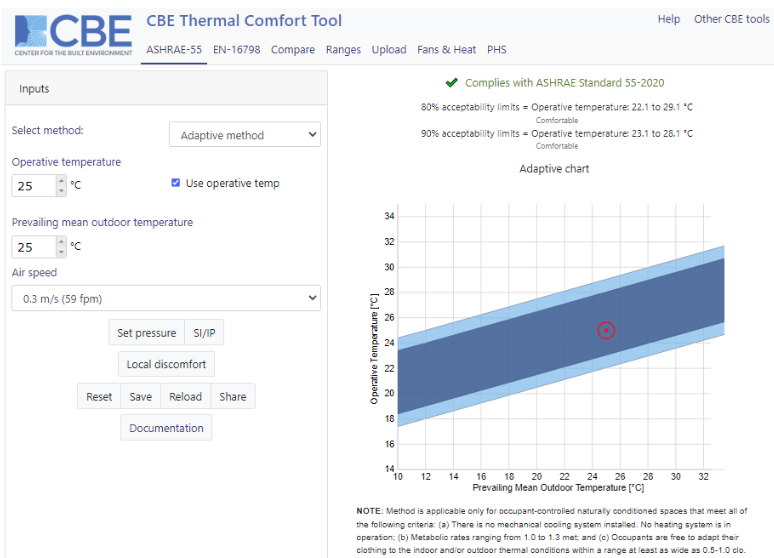

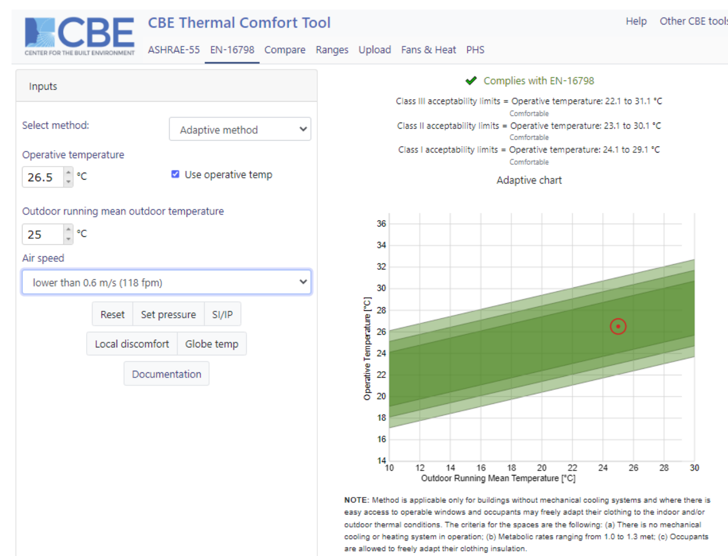

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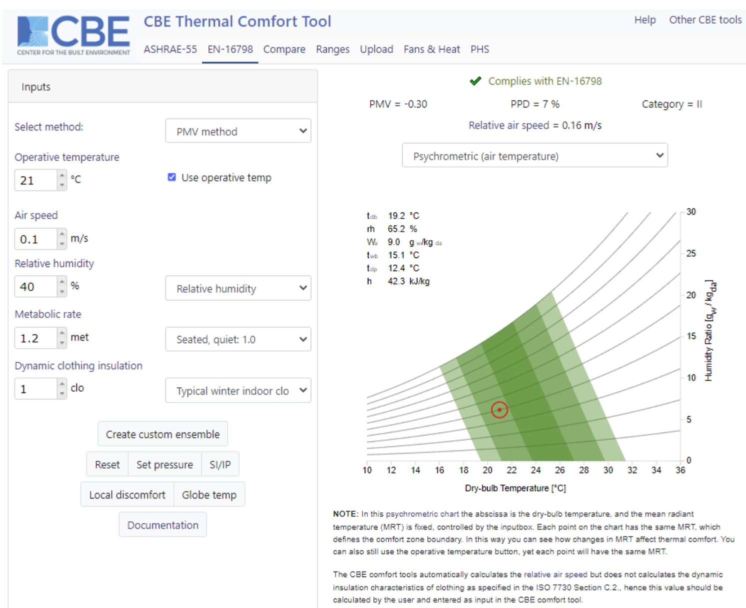
Def: *"Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range defined according to the **Fanger comfort model**"*



[Tartarini, F., Schiavon, S., Cheung, T., Hoyt, T., 2020. CBE Thermal Comfort Tool : online tool for thermal comfort calculations and visualizations. SoftwareX 12, 100563. https://doi.org/10.1016/j.softx.2020.100563](https://doi.org/10.1016/j.softx.2020.100563)

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- Degree-hours (Fanger)
- Percentage of time inside the Givoni comfort zone (1 m/s)
- Percentage of time inside the Givoni comfort zone (0 m/s)
- Number of hours within a certain temperature range

Def: *"The time during which the actual operative temperature exceeds the specified range (calculated according to the* ***adaptive*** *thermal comfort model) during the occupied hours is* ***weighted*** *with a factor which is a function of how many* ***degrees*** *the range has been exceeded."*

The weighting factor, wf_i, according with EN16798:

$$wf_i\Big|_{EN16798} = T_{op,i} - T_{op,limit}$$

The weighting factor, wf_i, according with ISO7730:

$$wf_i\Big|_{ISO7730} = 1 + \frac{\left|T_{op,i} - T_{op,limit}\right|}{\left|T_{op,comfort} - T_{op,limit}\right|}$$

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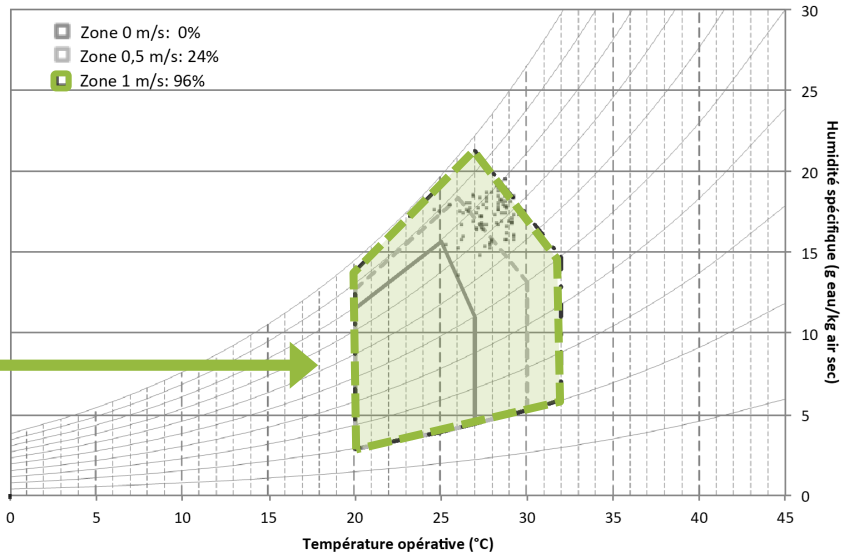
Def: *"Calculate the number or percentage of hours during the hours the building is occupied, when the operative temperature is inside the specified **comfort zone**."*



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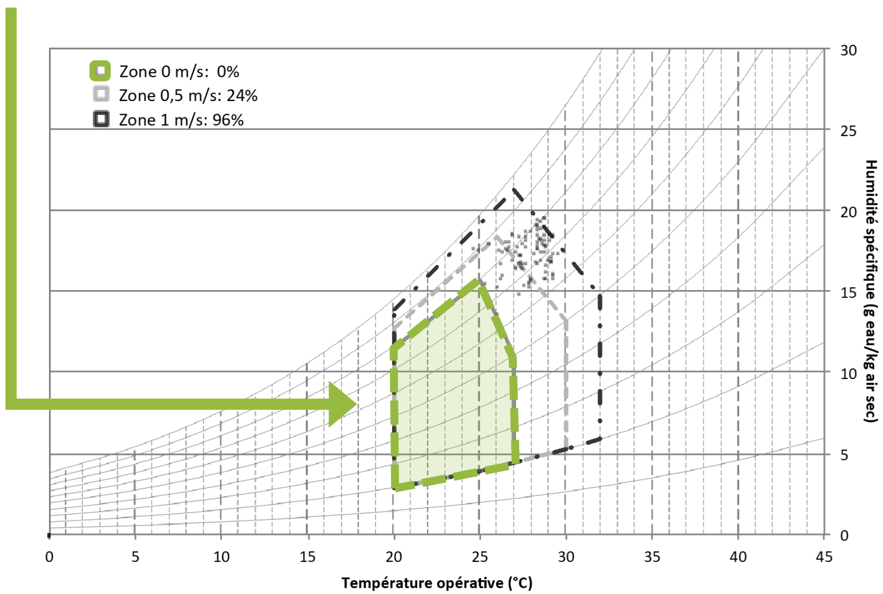

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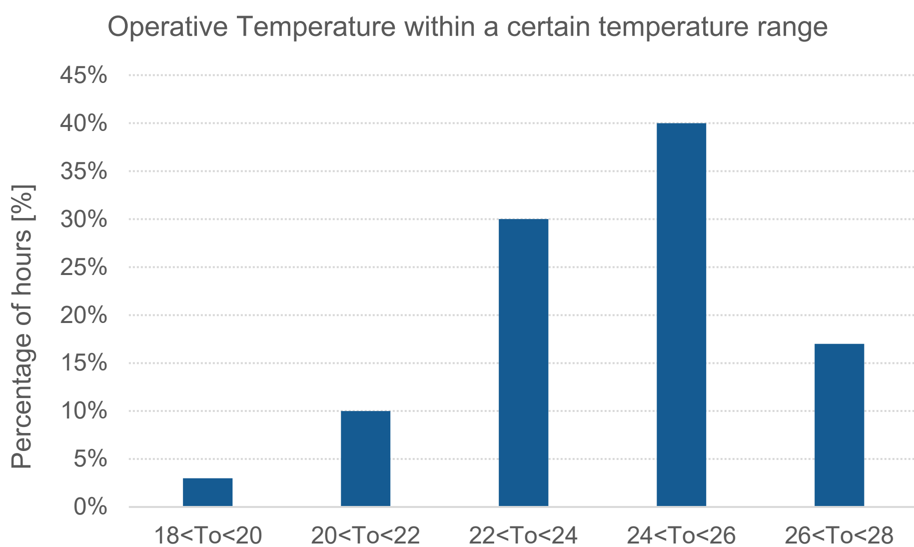

Operative temperature range [°C]	Number of hours	Percentage of hours
18<To<20	263	3%
20<To<22	876	10%
22<To<24	2628	30%
24<To<26	3504	40%
26<To<28	1489	17%

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Thank You!
Q & A

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